Division IV - EARTHQUAKE DESIGN

SECTION 1626A - GENERAL

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1626A.4 [For OSHPD 1 & 4] Configuration. *When the design of a structure, due to the unusual configuration of the structure or parts of the structure, does not provide at least the same safety against earthquake damage as provided by the applicable portions of this section when applied in the design of a similar structure of customary configuration, framing and assembly of materials, the enforcement agency shall withhold its approval.*

SECTION 1627A - DEFINITIONS *For the purposes of this division, certain terms are defined as follows:*

ADDITION *means any work which increases the floor or roof area or the volume of enclosed space of an existing building and is dependent on the structural elements of that facility for vertical or lateral support.*

ALTERATION *means any change in an existing building which does not increase and may decrease the floor or roof area or the volume of enclosed space.*

APPROVED EXISTING BUILDING [For OSHPD 1 and 4]*. Any building originally constructed in compliance with the requirements of the 1973 or subsequent edition of the California Building Code.*

ASSOCIATED STRUCTURAL ALTERATIONS *means any change affecting existing structural elements or requiring new structural elements for vertical or lateral support of an otherwise nonstructural alteration.*

BASE *is the level at which the earthquake motions are considered to be imparted to the structure or the level at which the structure as a dynamic vibrator is supported. This level does not necessarily coincide with the ground level.*

BASE SHEAR, V, *is the total design lateral force or shear at the base of a structure.*

HORIZONTAL BRACING SYSTEM *is a horizontal truss system that serves the same function as a diaphragm.*

HOSPITAL BUILDINGS *are hospital buildings and all other medical facilities as defined in Section 1250, Health and Safety Code.*

INCIDENTAL STRUCTURAL ALTERATIONS OR ADDITIONS *are alterations or additions which would not reduce the story lateral shear force-resisting capacity by more than 5 percent or increase the story shear by more than 5 percent in any existing story.*

LATERAL-FORCE-RESISTING-SYSTEM *is that part of the structural system designed to resist the Design Seismic Forces.*

MAJOR STRUCTURAL ALTERATIONS OR ADDITIONS *are those alterations or additions of greater extent than minor structural alterations or additions.*

MINOR STRUCTURAL ALTERATIONS OR ADDITIONS *are alterations or additions of greater extent than incidental structural alterations or additions which would not reduce the story shear lateral-force-resisting capacity by more than 10 percent or increase the base shear by more than 10 percent.*

MOMENT-RESISTING FRAME *is a frame in which members and joints are capable of resisting forces primarily by flexure.*

MOMENT-RESISTING WALL FRAME (MRWF) *is a masonry wall frame especially detailed to provide ductile behavior and designed in conformance with Section 2108A.2.5.*

NONREQUIRED STRUCTURAL ALTERATION *is any alteration of existing structural elements or provision of new structural elements which is not necessary for vertical or lateral support of other work and is initiated by the applicant primarily for the purpose of increasing the vertical or lateral load-carrying strength or stiffness of an existing building.*

NONSTRUCTURAL ALTERATION *is any alteration which neither affects existing structural elements nor requires new structural elements for vertical or lateral support and which does not increase the lateral shear force in any story by more than 5 percent.*

PΔ EFFECT *is the secondary effect on shears, axial forces and moments of frame members induced by the vertical loads acting on the laterally displaced building system.*

RECONSTRUCTION *means the rebuilding of any existing building to bring it into full compliance with these regulations.*

SHEAR WALL *is a wall designed to resist lateral forces parallel to the plane of the wall (sometimes referred to as vertical diaphragm or structural wall).*

SOFT STORY *is one in which the lateral stiffness is less than 70 percent of the stiffness of the story above. See Table 16A-L.*

SOIL-STRUCTURE RESONANCE *is the coincidence of the natural period of a structure with a dominant frequency of the ground motion.*

SPACE FRAME *is a three-dimensional structural system, without bearing walls, composed of members interconnected so as to function as a complete self-contained unit with or without the aid of horizontal diaphragms or floor-bracing systems.*

STRENGTH *is the capacity of an element or a member to resist factored load as specified in Chapters 16A, 18A, 19A, 21A and 22A.*

STRUCTURAL ELEMENTS *are floor or roof diaphragms, decking, joists, slabs, beams or girders, columns, bearing walls, retaining walls, masonry or concrete nonbearing walls exceeding one story in height, foundations, shear walls or other lateral- force-resisting members, and any other elements necessary to the vertical and lateral strength or stability of either the building as a whole or any of its parts, including connections between such elements.*

STRUCTURAL REPAIRS *are any changes affecting existing or requiring new structural elements primarily intended to correct the effects of deterioration or impending or actual failure, regardless of cause.*

STRUCTURE *is an assemblage of framing members designed to support gravity loads and resist lateral forces. Structures may be categorized as building structures or nonbuilding structures.*

SECTION 1638A [FOR OSHPD 1 & 4] – ADDITIONS, ALTERATIONS, REPAIRS AND SEISMIC RETROFIT TO EXISTING BUILDINGS OR STRUCTURES

Existing hospital buildings (as defined in Section 7-111, Part 1, Title 24, California Code of Regulations).

NOTE: *Alterations to lateral shear force-resisting capacity and story lateral shear forces shall be considered to be cumulative for purposes of defining incidental or minor alterations or additions. The percentage of cumulative changes shall be based on as-built conditions existing on March 7, 1973.*

1638A.1 Alterations. *For this section, alterations include any additions, alterations, repairs, and/or seismic retrofits to an existing hospital building or portions thereof. The provisions of Section 3403, "Additions, Alterations or Repairs" of Chapter 34 of the California Building Code shall apply for hospital buildings.*

1638A.2 Seismic Retrofit. *Any seismic retrofits of hospital buildings required by Article 2 and Article 11, Chapter 6, Part 1, Title 24, shall meet the requirements of Sections 1640A through 1649A.*

> ***EXCEPTION:*** *Hospital buildings evaluated to SPC 1 due to deficiencies identified by Article 10, Chapter 6, Part 1, Title 24, may be upgraded to SPC 2 by altering, repairing or seismically retrofitting these conditions in accordance with the requirements of Sections 1640A through 1649A.*

1638A.3 Alterations, additions and repairs to existing buildings or structures not required by Chapter 6, Part 1, Title 24.

1638A.3.1 Approved existing buildings. *Structural alterations or repairs may be made to approved buildings provided the entire building, as modified, including the structural alterations or repairs, conforms to Sections 1640A through 1649A requirements for the* *seismic structural performance category (SPC) of the building as determined in Chapter 6, Part 1, Title 24. Additions shall conform to the requirements of these regulations for new construction.*

1638A.3.2 Pre-1973 Buildings.

1638A.3.2.1 Incidental Structural Alterations, Additions or Repairs. *The existing structural elements affected by the alteration, addition or repair shall conform to the vertical load requirements of these regulations. Incidental structural additions will be permitted provided the additions meet these regulations for new construction using the importance factor,* **I***, equal to or greater than 1.0. Alterations or repairs to the existing lateral load-resisting system must meet the requirements of Sections 1640A through 1649A.*

1638A.3.2.2 Minor Structural Alterations, Additions or Repairs. *Minor structural alterations, additions or repairs will be permitted provided they meet the following: Alterations to existing gravity and/or lateral-load resisting system shall be made to conform to the requirements of Sections 1640A through 1649A; or additions shall meet all of the requirements of these regulations for new construction using an importance factor,* **I,** *equal to or greater than 1.0.*

1638A.3.2.3 Major Structural Alterations, Additions or Repairs. *Major structural alterations will be permitted provided the entire building, as modified, including the structural alterations or repairs, conforms to the requirements of Sections 1640A through 1649A for no less than SPC2. Additions shall meet the requirements of these regulations for new construction.*

It shall also be demonstrated by a written report submitted by the structural engineer, acceptable to the enforcement agency, that an investigation of the existing building structure shows it to be constructed in reasonable conformance with the submitted drawings and specifications.

1638A.3.3 *An alteration which involves the removal of one or more entire stories will be permitted if the lateral-load-resisting capacity of the remaining structure is not reduced.*

An alteration which involves the removal of other than one or more entire stories will be permitted in accordance with Sections 1640A through 1649A.

TABLE 16A-A—UNIFORM AND CONCENTRATED LOADS

USE OR OCCUPANCY		UNIFORM LOAD[1] (psf)	CONCENTRATED LOAD (pounds)
Category	**Description**	**X 0.0479 for kN/m²**	**X 0.004 48 for kN**
1. Access floor systems	Office use	50	2,000[2]
	Computer use	100	2,000[2]
2. Armories		150	0
3. Assembly areas[3] and auditoriums and balconies therewith	Fixed seating areas	50	0
	Movable seating and other areas	100	0
	Stage areas and enclosed platforms	125	0
4. Cornices and marquees		60[4]	0
5. Exit facilities[5]		100	0[6]
6. Garages	General storage and/or repair	100	[7]
	Private or pleasure-type motor vehicle storage	50	[7]
7. Hospitals	Wards and rooms	40	1,000[2]
	Laboratories, treatment rooms and operating rooms	*50*	*2,000[2]*
8. Libraries[12]	Reading rooms	60	1,000[2]
	Stack rooms	125	1,500[2]
9. Manufacturing[12]	Light	75	2,000[2]
	Heavy	125	3,000[2]
10. Offices[12]		50	2,000[2]
11. Printing plants[12]	Press rooms	150	2,500[2]
	Composing and linotype rooms	100	2,000[2]
12. Residential[8]	Basic floor area	40	0[6]
	Exterior balconies	60[4]	0
	Decks	40[4]	0
	Storage	40	0
13. Restrooms[9]			
14. Reviewing stands, grandstands, bleachers, and folding and telescoping seating		100	0
15 Roof decks	Same as area served or for the type of occupancy accommodated		
16. Schools	Classrooms	40	1,000[2]
17. Sidewalks, *pedestrian bridges* and driveways[12]	*Limited access*	100	[7]
	Public access	250	[7]
18. Storage[12]	Light	125	
	Heavy	250	
19. Stores[12]	*Retail*	75	2,000[2]
	Wholesale	100	3,000[2]
20. Pedestrian bridges and walkways		100	
21. Press box floor and roof with railing	*TV cameras and equipment*	*100*	*1,000[2]*
22. Dining areas	*Not used for assembly areas*	*100*	*1,000[2]*
23. Kitchens and serving areas		*50*	*1,000[2]*
24. Mechanical and electrical equipment areas[10]	*Open areas around equipment*	*50*	[11]
25. Shops[12]	*Light*	*75*	*2,000[2]*
	Heavy	*125*	*3,000[2]*

[1]See Section 1607A for live load reductions.

[2]See Section 1607A.3.3, first paragraph, for area of load application.

[3]Assembly areas include such occupancies as dance halls, drill rooms, gymnasiums, playgrounds, plazas, terraces and similar occupancies that are generally accessible to the public.

[4]When snow loads occur that are in excess of the design conditions, the structure shall be designed to support the loads due to the increased loads caused by drift buildup or a greater snow design as determined by the *enforcement agency*. See Section 1614A. For special-purpose roofs, see Section 1607A.4.4.

[5]Exit facilities shall include such uses as corridors serving an occupant load of 10 or more persons, exterior exit balconies, stairways, fire escapes and similar uses.

[6]Individual stair treads shall be designed to support a 300-pound (1.33 kN) concentrated load placed in a position that would cause maximum stress. Stair stringers may be designed for the uniform load set forth in the table.

[7]See Section 1607A.3.3, second paragraph, for concentrated loads. See Table 16A-B for vehicle barriers.

[8]Residential occupancies include private dwellings, apartments and hotel guest rooms *and dormitories.*
9Restroom loads shall not be less than the load for the occupancy with which they are associated, but need not exceed 50 pounds per square foot (2.4 kN/m²).
[10]See Part 7, Title 24, for elevator machine room floor loads and equipment loads.
[11]See Table 16A-B for equipment design loads.
[12]See Section 1607A.3.5 for posting requirements.

TABLE 16A-B—SPECIAL LOADS[1]

USE		VERTICAL LOAD	LATERAL LOAD
Category	Description	(pounds per square foot unless otherwise noted)	
		0.0479 for kN/m²	
1. Construction, public access at site (live load)	Walkway, see Section 3303.6	150	
	Canopy, see Section 3303.7	150	
2. Grandstands, reviewing stands, bleachers, and folding and telescoping seating (live load)	Seats and footboards	120[2]	See Footnote 3
3. Stage accessories (live load)	Catwalks	40	
	Followspot, projection and control rooms	50	
4. Ceiling framing (live load)	Over stages	20	
	All uses except over stages	10[4]	
5. Partitions and interior walls, see Sec. 1611A.5 (live load)			5
6. Elevators and dumbwaiters (dead and live loads)		2 X total loads[5]	
6.1 Elevator cars and dumbwaiters (dead and live load)		*See Part 7, Title 24*	*See Table 16A-O*
7. Mechanical and electrical equipment (dead load)		Total loads	*See Table 16A-O*
8. Cranes (dead and live loads)	Total load including impact increase	1.25 total load[6]	0.10 total load[7]
9. Balcony railings and guardrails	Exit facilities serving an occupant load greater than 50		50[8]
	Other than exit facilities		20[8]
	Components		25[9]
10. Vehicle barriers	See Section 311.2.3.5		6,000[10]
11. Handrails		See Footnote 11	See Footnote 11
12. Storage racks	Over 8 feet (2438 mm) high	Total loads[12]	See Table *16A-O*
12.1 Storage racks and wall-hung cabinets	*Racks over 5 feet (1524 mm) high*	Total loads[12]	See Table 16A-O
13. Fire sprinkler structural support		250 pounds (1112 N) plus weight of water-filled pipe[13]	See Table *16A-O*
14. Explosion exposure	Hazardous occupancies, see Section 307.10		

[1]The tabulated loads are minimum loads. Where other vertical loads required by this code or required by the design would cause greater stresses, they shall be used.
[2]Pounds per lineal foot (14.6 for N/m).
[3]Lateral sway bracing loads of 24 pounds per foot (350 N/m) parallel and 10 pounds per foot (145.9 N/m) perpendicular to seat *boards at the standard level. Sway loads need not be applied simultaneously with other lateral loads. Allowable stresses for allowable stress design may be increased one third when considering sway loads acting alone or when combined with vertical loads* and footboards.
[4]Does not apply to ceilings that have sufficient total access from below, such that access is not required within the space above the ceiling. Does not apply to ceilings if the attic areas above the ceiling are not provided with access. This live load need not be considered as acting simultaneously with other live loads imposed upon the ceiling framing or its supporting structure.
[5]*Not adopted by the State of California.*
[6]The impact factors included are for cranes with steel wheels riding on steel rails. They may be modified if substantiating technical data acceptable to the building official is submitted. Live loads on crane support girders and their connections shall be taken as the maximum crane wheel loads. For pendant-operated traveling crane support girders and their connections, the impact factors shall be 1.10.
[7]This applies in the direction parallel to the runway rails (longitudinal). The factor for forces perpendicular to the rail is 0.20 the transverse traveling loads (trolley, cab, hooks and lifted loads). Forces shall be applied at top of rail and may be distributed among rails of multiple rail cranes and shall be distributed with due regard for lateral stiffness of the structures supporting these rails.
[8]A load per lineal foot (14.6 for N/m) to be applied horizontally at right angles to the top rail.

[9]Intermediate rails, panel fillers and their connections shall be capable of withstanding a load of 25 pounds per square foot (1.2 kN/m^2) applied horizontally at right angles over the entire tributary area, including openings and spaces between rails. Reactions due to this loading need not be combined with those of Footnote 8.

[10]A horizontal load in pounds (N) applied at right angles to the vehicle barrier at a height of 18 inches (457 mm) above the parking surface. The force may be distributed over a 1-foot-square (304.8-millimeter-square) area.

[11]The mounting of handrails shall be such that the completed handrail and supporting structure are capable of withstanding a load of at least 200 pounds (890 N) applied in any direction at any point on the rail. These loads shall not be assumed to act cumulatively with Item 9.

[12]Vertical members of storage racks shall be protected from impact forces of operating equipment, or racks shall be designed so that failure of one vertical member will not cause collapse of more than the bay or bays directly supported by that member.

The minimum vertical design live load shall be as follows:

Paper media:

12-inch-deep (305 mm) shelf — 33 pounds per lineal foot (482 N/m)
15-inch-deep (381 mm) shelf — 41 pounds per lineal foot (599 N/m), or
33 pounds per cubic foot (5.2 kN/m^3) per total volume of the rack or cabinet, whichever is less.

The minimum vertical design live load shall be as follows: (continued)

Film media:

18-inch-deep (457 mm) shelf — 100 pounds per lineal foot (1460 N/m), or
50 pounds per cubic foot (7.85 kN/m^3) per total volume of the rack or cabinet, whichever is less.

Other media:

20 pounds per cubic foot (3.14 kN/m^3) or 20 pounds per lineal foot (292 N/m), whichever is less, but not less than actual loads.

[13]The 250-pound (1.11 kN) load is to be applied to any single fire sprinkler support point but not simultaneously to all support joints.

TABLE 16A-C—MINIMUM ROOF LIVE LOADS...

TABLE 16A-D—MAXIMUM ALLOWABLE DEFLECTION FOR STRUCTURAL MEMBERS[1]

TYPE OF MEMBER	MEMBER LOADED WITH LIVE LOAD ONLY *(L.)*	MEMBER LOADED WITH LIVE LOAD PLUS DEAD LOAD *(L. + K.D.)*
Roof member supporting plaster or floor member	*l*/360	*l*/240
Roof member without plaster ceiling	*L/240*	*L/180*

[1]Sufficient slope or camber shall be provided for flat roofs in accordance with Section 1611A.7.
L.-live load.
D.- dead load.
K.- factor as determined by Table 16A-E.
l- length of member in same units as deflection.

TABLE 16A-E—VALUE OF "K"

WOOD			
Unseasoned	Seasoned[1]	REINFORCED CONCRETE[2]	STEEL
1.0	0.5	$T/(1+50\rho')$	0

[1]Seasoned lumber is lumber having a moisture content of less than 16 percent at time of installation and used under dry conditions of use such as in covered structures.

[2]See also Section 1909A for definitions and other requirements.
ρ' shall be the value at midspan for simple and continuous spans, and at support for cantilevers. Time-dependent factor T for sustained loads may be taken equal to:

five years or more	2.0	six months	*1.2*
twelve months	*1.4*	three months	1.0

TABLE 16A-F—WIND STAGNATION PRESSURE (q_s) AT STANDARD HEIGHT OF 33 FEET (10 058mm)...

TABLE 16A-G—COMBINED HEIGHT, EXPOSURE AND GUST FACTOR COEFFICIENT (C_e)...

TABLE 16A-H—PRESSURE COEFFICIENTS (C_q)

STRUCTURE OR PART THEREOF	DESCRIPTION	C_q FACTOR
1. Primary frames and systems	Method 1 (Normal force method)	
	Walls:	
	Windward wall	0.8 inward
	Leeward wall	0.5 outward
	Roofs[1]:	
	Wind perpendicular to ridge	
	Leeward roof or flat roof	0.7 outward
	Windward roof	
	less than 2:12 (16.7%)	0.7 outward
	Slope 2:12 (16.7%) to less than 9:12 (75%)	0.9 outward or 0.3 inward
	Slope 9:12 (75%) to 12:12 (100%)	0.4 inward
	Slope > 12:12 (100%)	0.7 inward
	Wind parallel to ridge and flat roofs	0.7 outward
	Method 2 (Projected area method)[13]	
	On vertical projected area	
	Structures 40 feet (12 192 mm) or less in height	1.3 horizontal any direction
	Structures over 40 feet (12 192 mm) in height	1.4 horizontal any direction
	On horizontal projected area1	0.7 upward
2. Elements and components not in areas of discontinuity[2]	Wall elements	1.2 inward
	All structures	1.2 outward
	Structures other than partially enclosed	1.6 outward
	Partially enclosed structures	1.3 inward or outward
	Parapets walls	
	Roof elements[9]	
	Structures other than partially enclosed	
	Slope <7:12 (58.3%)	1.3 outward
	Slope 7:12 (58.3%) to 12:12 (100%)	1.3 outward or inward
	Slope > 12:12 (100%)	1.2 outward or inward
	Partially enclosed structures	
	Slope > 2:12 (16.7%)	1.7 outward
	Slope 2:12 (16.7%) to 7:12 (58.3%)	1.6 outward or 0.8 inward
	Slope > 7:12 (58.3%) to 12:12 (100%)	1.7 outward or inward
	Slope > 12:12 (100%)	1.6 outward or 1.2 inward
3. Elements and components in areas of discontinuities[2,4,5]	Wall corners[6]	1.5 outward or 1.2 inward
	Roof eaves, rakes or ridges without overhangs[11, 12]	
	Slope < 2:12 (16.7%)	2.3 upward
	Slope 2:12 (16.7%) to 7:12 (58.3%)	2.6 outward
	Slope > 7:12 (58.3%) to 12:12 (100%)	1.6 outward
	Slope > 12:12 (100%)	*1.6 outward or inward*
	For slopes less than 2:12 (16.7%)	
	Overhangs at roof eaves, rakes or ridges, and canopies	0.5 added to values above
4. Chimneys, tanks and solid towers	Square or rectangular	1.4 any direction
	Hexagonal or octagonal	1.1 any direction
	Round or elliptical	0.8 any direction
5. Open-frame towers[12, 13]	Square and rectangular	
	Diagonal	4.0
	Normal	3.6
	Triangular	3.2
6. Tower accessories (such as ladders, conduit, lights and elevators)	Cylindrical members	
	2 inches (51 mm) or less in diameter	1.0
	Over 2 inches (51 mm) in diameter	0.8
	Flat or angular members	1.3
7. Signs, flagpoles, lightpoles, minor structures[12,13]		1.4 any direction

[1]For one story or the top story of multistory partially enclosed structures, an additional value of 0.5 shall be added to the outward C_q. The most critical combination shall be used for design. For definition of partially enclosed structures, see Section 1616A.

[2]Cq values listed are for 10-square-foot (0.93 m2) tributary areas. For tributary areas of 100 square feet (9.29 m2), the value of *0.2* may be subtracted from Cq, except for areas at discontinuities with slopes less than 7 units vertical in 12 units horizontal (58.3% slope) where the value of 0.8 may be subtracted from Cq. Interpolation may be used for tributary areas between 10 and 100 square feet (0.93 m2 and 9.29 m2). For tributary areas greater than 1,000 square feet (92.9 m2), use primary frame values.

[3]*Not adopted by the State of California.*

[4]Local pressures shall apply over a distance from the discontinuity of 10 feet (3048 mm) or 0.1 times the least width of the structure, whichever is smaller.

[5]Discontinuities at wall corners or roof ridges are defined as discontinuous breaks in the surface where the included interior angle measures 170 degrees or less.
[6]*Not adopted by the State of California.*
[7]Wind pressures shall be applied to the total normal projected area of all elements on one face. The forces shall be assumed to act parallel to the wind direction.
[8]*Not adopted by the State of California.*
[9]*Miscellaneous items such as skylights and smoke vents shall be designed using Cq for the appropriate elements and component.*
[10]*Appendages such as mechanical units or screens may be designed per Table 16A-H, Method 2.*
[11]*For overhangs, the coefficient shall be applied as follows:*
[11.1] *0.8 to the underside of framing or soffit;*
[11.2] *Cq-0.8 to the top of roof as suction.*
[12]*Minimum wind design pressure for flagpoles and lightpoles shall be 25 pounds per square foot (1.2 kN/m²).*
[13]*Factors for cylindrical elements are two thirds of those for flat or angular elements.*

TABLE 16A-I—SEISMIC ZONE FACTOR Z

ZONE	1	2A	2B	3	4
Z	0.075	0.15	0.20	0.30	0.40

NOTE: The zone shall be determined from the seismic zone map in Figure 16A-2 *and Section 1629A.4.1.*

TABLE 16A-J—SITE COEFFICIENTS...

TABLE 16A-K—OCCUPANCY CATEGORY

OCCUPANCY CATEGORY	OCCUPANCY OR FUNCTIONS OF STRUCTURE	SEISMIC IMPORTANCE FACTOR, I	SEISMIC IMPORTANCE[1] FACTOR, I_p	WIND IMPORTANCE FACTOR, I_w
1. Essential facilities[2]	*Hospitals and other medical facilities as defined in Section 1250, Health and Safety Code.* Group I, Division 1 Occupancies having surgery and emergency treatment areas Fire and police stations, *sheriffs offices, California Highway Patrol offices and California State Police Offices* *Municipal, county and state government disaster operation and communication centers deemed vital in emergencies* *For wind only, building areas where the primary occupancy is for assembly use for more than 300 people and portions of connecting or adjacent structures, the collapse of which would endanger the assembly area or restrict egress from it. (For earthquake, see Category 3.)* Garages and shelters for emergency vehicles and emergency aircraft Structures and shelters in emergency-preparedness centers Aviation control towers Structures and equipment in government communication centers and other facilities required for emergency response Standby power-generating equipment for Category 1 facilities Tanks or other structures containing housing or supporting water or other fire-suppression material or equipment required for the protection of Category 1, 2 or 3 structures	*1.50*	1.50	1.15
2. Hazardous facilities	Group H, Divisions 1, 2, 6 and 7 Occupancies and structures therein housing or supporting toxic or explosive chemicals or substances Nonbuilding structures housing, supporting or containing quantities of toxic or explosive substances that, if contained within a building, would cause that building to be classified as a Group H, Division 1, 2 or 7 Occupancy	1.25	1.50	1.15
3. Special occupancy structures[3]	Group A, Divisions 1, 2 and 2.1 Occupancies *For earthquake only, covered structures whose primary occupancy is public assembly-capacity greater than 300 persons. (For wind, see Category 1.)* Buildings housing Group E, Divisions 1 and 3 Occupancies with a capacity greater than 300 students Buildings housing Group B Occupancies used for college or adult education with a capacity greater than 500 students Group I, Divisions 1 and 2 Occupancies with 50 or more resident incapacitated patients, but not included in Category 1 Group I, Division 3 Occupancies All structures with an occupancy greater than 5,000 persons Structures and equipment in power-generating stations, and other public utility facilities not included in Category 1 or Category 2 above, and required for continued operation	*1.15*	*1.15*	1.00
4. Standard occupancy structures[3]	All structures housing occupancies or having functions not listed in Category 1, 2 or 3 and Group U Occupancy towers	1.00	1.00	1.00
5. Miscellaneous structures	Group U Occupancies except for towers	1.00	1.00	1.00

[1]The limitation of *Ip* for panel connections in Section 1633*A*.2.4 shall be 1.0 for the entire connector.
[2]Structural observation requirements are given in Section 1702*A*.
[3]For anchorage of machinery and equipment required for life-safety systems, the value of *Ip* shall be taken as 1.5.

TABLE 16A-L—VERTICAL STRUCTURAL IRREGULARITIES

RREGULARITY TYPE AND DEFINITION	REFERENCE SECTION
1. Stiffness irregularity-soft story A soft story is one in which the lateral stiffness is less than 70 percent of that in the story above or less than 80 percent of the average stiffness of the three stories above.	1629*A*.8.4, Item 2
2. Weight (mass) irregularity Mass irregularity shall be considered to exist where the effective mass of any story is more than 150 percent of the effective mass of an adjacent story. A roof that is lighter than the floor below need not be considered.	1629*A*.8.4, Item 2
3. Vertical geometric irregularity Vertical geometric irregularity shall be considered to exist where the horizontal dimension of the lateral- force-resisting system in any story is more than 130 percent of that in an adjacent story. One-story penthouses need not be considered.	1629*A*.8.4, Item 2
4. In-plane discontinuity in vertical lateral-force-resisting element An in-plane offset of the lateral-load-resisting elements greater than the length of those elements.	1630*A*.8.2
5. Discontinuity in capacity-weak story A weak story is one in which the ratio of the story strength to the story shear is less than 80 percent of that in the story above. The story strength is the strength of all seismic-resisting elements sharing the story shear for the direction under consideration. The load deformation characteristics of the elements shall be considered so that the strength is determined for compatible deformations.	1629*A*.9.1

TABLE 16A-M—PLAN STRUCTURAL IRREGULARITIES…

TABLE 16A-N—STRUCTURAL SYSTEMS[1]

BASIC STRUCTURAL SYSTEM[2]	LATERAL-FORCE-RESISTING SYSTEM DESCRIPTION	*R*	Ω_o	HEIGHT LIMIT FOR SEISMIC ZONES 3 AND 4 (feet) X 304.8 for mm
1. Bearing wall system	1. Light-framed walls with shear panels			
	a. Wood structural panel walls for structures three stories or	5.5	2.8	65
	less	4.5	2.8	65
	b. All other light-framed walls			
	2. Shear walls	4.5	2.8	160
	a. Concrete	4.5	2.8	160
	b. Masonry	2.8	2.2	65
	3. Light steel-framed bearing walls with tension-only bracing			
	4. Braced frames where bracing carries gravity load	~~4.4~~	~~2.2~~	~~160~~
	a. *Not adopted by the State of California.*	-	-	-
	b. *Not adopted by the State of California.*	2.8	2.2	65
	c. Heavy timber			
2. Building frame system	1. Steel eccentrically braced frame (EBF)	7.0	2.8	240
	2. Light-framed walls with shear panels			
	a. Wood structural panel walls for structures three stories or	6.5	2.8	65
	less	5.0	2.8	65
	b. All other light-framed walls			
	3. Shear walls	5.5	2.8	240
	a. Concrete	5.5	2.8	160
	b. Masonry			
	4. Ordinary braced frames	~~5.6~~	~~2.2~~	~~160~~
	a. *Not adopted by the State of California.*	-	-	-
	b. *Not adopted by the State of California.*	5.6	2.2	65
	c. Heavy timber			
	5. Special concentrically braced frames	6.4	2.2	240
	a. Steel			
3. Moment-resisting frame system	1. Special moment-resisting frame (SMRF)			
	a. Steel	8.5	2.8	N.L.
	b. Concrete[4]	8.5	2.8	N.L.
	2. Masonry moment-resisting wall frame (MMRWF)	6.5	2.8	160
	3. *Not adopted by the State of California.*	-	-	-
	4. Ordinary moment-resisting frame (OMRF)			
	a. *Not adopted by the State of California*	-	-	-
	b. *Not adopted by the State of California.*	-	-	-
	5. Special truss moment frames of steel (STMF)	6.5	2.8	240
4. Dual systems	1. Shear walls			
	a. Concrete with SMRF	8.5	2.8	N.L.
	b. *Not adopted by the State of California*	~~4.2~~	~~2.8~~	~~160~~
	c. *Not adopted by the State of California.*			
	d. Masonry with SMRF	-	-	-
	e. *Not adopted by the State of California*	5.5	2.8	160
	f. *Not adopted by the State of California.*	~~4.2~~	~~2.8~~	~~160~~
	g. Masonry with masonry MMRWF	-	-	-
	2. Steel EBF	6.0	2.8	160
	a. With steel SMRF			
	b. *Not adopted by the State of California.*	8.5	2.8	N.L.
	3. Ordinary braced frames	~~4.2~~	~~2.8~~	~~160~~
	a. *Not adopted by the State of California*			
	b. *Not adopted by the State of California*	~~6.5~~	~~2.8~~	~~N.L.~~
	c. *Not adopted by the State of California.*	~~4.2~~	~~2.8~~	~~160~~
	d. *Not adopted by the State of California.*	-	-	-
	4. Special concentrically braced frames	-	-	-
	a. Steel with steel SMRF			
	b. *Not adopted by the State of California*	7.5	2.8	N.L.
		~~4.2~~	~~2.8~~	~~160~~
5. Cantilevered column building systems	1. Cantilevered column elements	2.2	2.0	35[5]
6. Shear wall-frame interaction systems	1. *Not adopted by the State of California.*	-	-	-
7. Undefined systems	See Sections 1629A.6.7 and 1629A.9.2	-	-	-

N.L.-no limit

[1]See Section 1630*A*.4 for combination of structural systems.

[2]Basic structural systems are defined in Section 1629*A*.6.

[3]*Not adopted by the State of California.*

[4]Includes precast concrete conforming to Section 1921*A*.2.7.

[5]*Not adopted by the State of California.*

[6] *Not adopted by the State of California.*
[7] **Total height of the building including cantilevered columns.**
[8] *Not adopted by the State of California.*

TABLE 16*A*-O—HORIZONTAL FORCE FACTORS, a_p AND R_p

ELEMENTS OF STRUCTURES AND NONSTRUCTURAL COMPONENTS AND EQUIPMENT[1]	a_p	R_p	FOOTNOTE
1. Elements of Structures A. Walls including the following: (1) Unbraced (cantilevered) parapets.	2.5	3.0	
(2) Exterior walls at or above the ground floor and parapets braced above their centers of gravity.	1.0	3.0	2
(3) All interior-bearing and nonbearing walls.	1.0	3.0	2, *8*
B. Penthouse (except when framed by an extension of the structural frame).	2.5	4.0	
C. Connections for prefabricated structural elements other than walls. See also Section 1632*A*.2.	1.0	3.0	3, *20*
2. Nonstructural Components A. Exterior and interior ornamentations and appendages.	2.5	3.0	*20*
B. Chimneys, stacks and trussed towers supported on or projecting above the roof: (1) Laterally braced or anchored to the structural frame at a point below their centers of mass.	2.5	3.0	
(2) Laterally braced or anchored to the structural frame at or above their centers of mass.	1.0	3.0	
C. Signs and billboards.	2.5	3.0	
D. Storage racks (include contents) *with upper storage level more than 5 feet (1524 mm) in height*	2.5	4.0	4, *23*
E. Permanent floor-supported cabinets and book stacks more than 6 feet (1829 mm) in height (include contents).	1.0	3.0	5, *20, 22, 23*
F. Anchorage and lateral bracing for suspended ceilings and light fixtures.	1.0	3.0	3, 6, 7, 8, *24*
G. Access floor systems.	1.0	3.0	9, *20*
H. Masonry or concrete fences over 6 feet (1829 mm) high.	1.0	3.0	
I. Partitions.	1.0	3.0	*8*
J. Wall hung cabinets and storage shelving (plus contents)	*1.0*	*3.0*	
3. Equipment A. Tanks and vessels (include contents), including support systems.	1.0	3.0	*20*
B. Electrical, mechanical and plumbing equipment and associated conduit and ductwork and piping, *and machinery. In hospitals and essential services buildings, this includes all piping, electrical conduits, cable trays and air-handling ducting necessary to the continuing operation of the facility.*	1.0	3.0	5, 10, 11, 12, 13, 14, 15, 16, *20*
C. Any flexible equipment laterally braced or anchored to the structural frame at a point below their center of mass.	2.5	3.0	5, 10, 14, 15, 16, *20*
D. Anchorage of emergency power supply systems and essential communications equipment. Anchorage and support systems for battery racks and fuel tanks necessary for operation of emergency equipment. See also Section 1632*A*.2.	*1.3*	3.0	17, 18, *20, 21*
E. Temporary containers with flammable or hazardous materials.	1.0	3.0	19
F. Power cable-driven elevators or hydraulic elevators with lifts over 5 feet (1524 mm): *(1) Hoistway structural framing providing the support for guide rail brackets*			*25*
(2) Guide rails and guide rail brackets			
(3) Car and counterweight auxiliary guiding members or retainer plates			
(4) Driving machinery, pump unit tanks operating devices and control equipment cabinets			
4. Other Components A. Rigid components with ductile material and attachments.	1.0	3.0	1, *20*
B. Rigid components with nonductile material or attachments.	1.0	1.5	1, *20*
C. Flexible components with ductile material and attachments.	2.5	3.0	1, *20*
D. Flexible components with nonductile material or attachments.	2.5	1.5	1, *20*

[1]See Section 1627*A* for definitions of flexible components and rigid components. *See Section 1632A for formula using* a_p. *Horizontal forces are to be applied in any horizontal direction. Welded, bolted or other intermittent connections such as inserts for anchorage of nonstructural components shall not be allowed the one-third increase in allowable stress permitted in Section 1612A.3.2.*

[2]See Sections 1633*A*.2.4 and 1633*A*.2.8 for concrete and masonry walls and Section 1632A.2 for connections for panel connectors for panels.

[3]Applies to Seismic Zones 2, 3 and 4 only.

[4]Ground supported steel storage racks may be designed using the provisions of Section 1634*A*. Chapter 22*A*, Division VI, may be used for design, provided seismic design forces are equal to or greater than those specified in Section 1632*A*.5 or 1634*A*.5, as appropriate.

[5]Only attachments, anchorage or restraints need be designed.

[6]Ceiling weight shall include all light fixtures and other equipment or partitions that are laterally supported by the ceiling. For purposes of determining the seismic force, a ceiling weight of not less than 4 psf (0.19 kN/m2) shall be used.

[7]Ceilings constructed of lath and plaster or gypsum board screw or nail attached to suspended members that support a ceiling at one level extending from wall to wall need not be analyzed, provided the walls are not over 50 feet (15 240 mm) apart.

[8]Light fixtures and mechanical services installed in metal suspension systems for acoustical tile and lay-in panel ceilings shall be independently supported from the structure above as specified in UBC Standard 25-2, Part III. *See also Section 1611A.5 for minimum load and deflection criteria for interior partitions.*

[9]W_p for access floor systems shall be the dead load of the access floor system plus 25 percent of the floor live load plus a 10-psf (0.48 kN/m2) partition load allowance.

[10]Equipment includes, but is not limited to, boilers, chillers, heat exchangers, pumps, air-handling units, cooling towers, control panels, motors, switchgear, transformers and life-safety equipment. It shall include major conduit, ducting and piping, which services such machinery and equipment and fire sprinkler systems. See Section 1632A.2 for additional requirements for determining a_p for nonrigid or flexibly mounted equipment.

[11] *Deleted*

[12]Seismic restraints may be omitted from electrical raceways, such as cable trays, conduit and bus ducts, if all the following conditions are satisfied:

[12.1] Lateral motion of the raceway will not cause damaging impact with other systems.

[12.2] Lateral motion of the raceway does not cause loss of system vertical support.

[12.3] Rod-hung supports of less than 12 inches (305 mm) in length have top connections that cannot develop moments.

[12.4] Support members cantilevered up from the floor are checked for stability.

[13]Piping, ducts and electrical raceways, which must be functional following an earthquake, spanning between different buildings or structural systems shall be sufficiently flexible to withstand relative motion of support points assuming out-of-phase motions.

[14]Vibration isolators supporting equipment shall be designed for lateral loads or restrained from displacing laterally by other means. Restraint shall also be provided, which limits vertical displacement, such that lateral restraints do not become disengaged. a_p and R_p for equipment supported on vibration isolators shall be taken as 2.5 and 1.5, respectively, except that if the isolation mounting frame is supported by shallow or expansion anchors, the design forces for the anchors calculated by Formula (32*A*-1), (32*A*-2) or (32*A*-3) shall be additionally multiplied by a factor of *1.3.*

[15]Equipment anchorage shall not be designed such that lateral loads are resisted by gravity friction (e.g., friction clips).

[16]Expansion anchors, which are required to resist seismic loads in tension, shall not be used where operational vibrating loads are present.

[17]Movement of components within electrical cabinets, rack- and skid-mounted equipment and portions of skid-mounted electromechanical equipment that may cause damage to other components by displacing, shall be restricted by attachment to anchored equipment or support frames.

[18]Batteries on racks shall be restrained against movement in all directions due to earthquake forces.

[19]Seismic restraints may include straps, chains, bolts, barriers or other mechanisms that prevent sliding, falling and breach of containment of flammable and toxic materials. Friction forces may not be used to resist lateral loads in these restraints unless positive uplift restraint is provided which ensures that the friction forces act continuously.

[20]*The component anchorage shall be designed for the horizontal force,* F_p, *acting simultaneously with a vertical seismic force equal to one third of the horizontal force,* F_p.

[21]*Emergency equipment should be located where there is the least likelihood of damage due to earthquake. Such equipment should be located at ground level, and where it can be easily maintained to assure its operation during an emergency.*

[22]*Floor-supported storage racks, cabinets or book stacks not more than 5 feet (1524 mm) in height need not be anchored if the width of the supporting base or width between the exterior legs is equal to or greater than two thirds the height. In addition to gravity loads, storage racks or cabinets shall be deigned and constructed to resist the horizontal force,* F_p, *with the base assumed to be anchored.*

[23]*Mobile storage racks or cabinets mounted on wheels and not restrained by fixed tracks are not subject to approval by the enforcement agency when the rack or cabinet is not more than 5 feet (1524 mm) in height and the width of the supporting base or width between the exterior legs/wheels is equal to or greater than two thirds the height. All such racks or cabinets shall be restrained to prevent movement when not in use. Movable storage racks or cabinets mounted on wheels or glides restrained by fixed tracks shall be designed and constructed to resist the horizontal force,* F_p, *with the base of the rack or cabinet assumed to be anchored. Provisions shall be made to resist translation perpendicular to the track and overturning both perpendicular and parallel to the track.*

[24]*Suspension systems for light fixtures which have passed shaking table tests approved by the enforcement agency, or which, as installed, are free to swing a minimum of 45 degrees from the vertical in all directions without contacting obstructions, shall be assumed to comply with the lateral-force requirements of Section 1632A.2. Unless the cable-type, free-swinging suspension systems shall have a safety wire or cable attached to the fixture and structure at each support capable of supporting four times the supported load.*

[25]*See Section 1633A.2.13.*

TABLE 16A-P—R AND Ω_o FACTORS FOR NONBUILDING STRUCTURES

STRUCTURE TYPE	R	Ω_o
1. Vessels, including tanks and pressurized spheres, on braced or unbraced legs.	2.2	2.0
2. Cast-in-place concrete silos and chimneys having walls continuous to the foundations.	3.6	2.0
3. Distributed mass cantilever structures such as stacks, chimneys, silos and skirt-supported vertical vessels.	2.9	2.0
4. Trussed towers (freestanding or guyed), guyed stacks and chimneys.	2.9	2.0
5. Cantilevered column-type structures.	~~2.2~~ -	~~2.0~~ -
5.1 Single-column structures	2.2	2.0
5.2 Multicolumn structures with strut ties capable of developing the capacity of the column	2.9	2.0
6. Cooling towers.	3.6	2.0
7. Bins and hoppers on braced or unbraced legs.	2.9	2.0
8. Storage racks.	3.6	2.0
9. Signs and billboards.	3.6	2.0
10. Amusement structures and monuments.	2.2	2.0
11. All other self-supporting structures not otherwise covered.	2.9	2.0

TABLE 16*A*-Q—SEISMIC COEFFICIENT C_a...
TABLE 16*A*-R—SEISMIC COEFFICIENT C_V…
TABLE 16*A*-S—NEAR-SOURCE FACTOR N_a…
TABLE 16A-T—NEAR-SOURCE FACTOR N_V…
TABLE 16*A*-U—SEISMIC SOURCE TYPE…

TABLE 16A-V—MAXIMUM DIAPHRAGM DIMENSION RATIOS

	HORIZONTAL DIAPHRAGMS MAXIMUM SPAN-WIDTH RATIOS[1]		*VERTICAL DIAPHRAGMS MAXIMUM HEIGHT-WIDTH RATIOS*
	Masonry and Concrete Walls	*Wood and Light-steel Walls*	
Concrete	*3:1*		
Steel deck (continuous sheet in a single plane)	*3:1*	*3:1*	
Steel deck (without continuous sheet)	*2:1*	*3:1*	
Poured reinforced gypsum roofs	*3:1*	*3:1*	
Plywood (nailed all edges)	*3:1*	*3:1*	*2:1*[4]
Plywood (nailed to supports only, blocking may be omitted between joists)	*2 1/2:1*[2]	*3:1*	*Footnote 3*
Diagonal sheathing (special)	*Footnote 3*	*3:1*	*1:1*
Diagonal sheathing (conventional construction)	*Footnote 3*	*2:1*	*Footnote 5*

[1]Where lateral forces are resisted primarily by rotation, span-width ratios shall not exceed one half of the tubular values. In concrete or masonry buildings, wood diaphragms or diaphragms of similar flexibility shall not be permitted to resist lateral forces by rotation.
[2]The use of unblocked horizontal plywood diaphragms for buildings having masonry or reinforced concrete walls shall be limited to one-story buildings or to the roof of a top story.
[3]Not permitted.
[4]See Section 2307A for use with masonry or concrete walls.
[5]See Section 2315A.3.1

TABLE 16A-W—MAXIMUM ALLOWABLE DEFLECTION NORMAL TO THE SURFACE OF WALL ELEMENT UNDER LATERAL FORCE LOADING

WALL ELEMENT	LOADING CONDITION	MAXIMUM ALLOWABLE DEFLECTION[1]
Exterior walls-brittle construction	*Seismic or wind*	*L/240*
Exterior walls-flexible construction	*Seismic or wind*	*L/180*
Veneered walls, anchored veneers and adhered veneers over 1 inch (25 mm) thick, including the mortar backing	*Seismic*	*L/480*

[1]L is the span between vertical or horizontal supports.

Division VI-R

EARTHQUAKE EVALUATION AND DESIGN FOR RETROFIT OF EXISTING HOSPITAL BUILDINGS

Section 1640A - GENERAL

1640A.1 Purpose. *All modifications, alterations, and/or repairs to existing structures or portions thereof shall, at a minimum, be designed and constructed to resist the effects of seismic ground motions as provided in this division. When applicable, the structural system shall be evaluated by the design professional of record and, if not meeting or exceeding the minimum seismic design purpose of this division, shall be retrofitted in compliance with these requirements.*

1640A.1.1 Minimum Seismic Design. *The purpose of this division is to provide a minimum level of seismic performance. At this essential life-safety level (seismic performance category SPC-2), in general, persons in and around the building will be able to safely exit or be evacuated from the building or its vicinity following an earthquake. It does not mean that persons will not be injured or not be in need of medical attention. This level of seismic performance is presumed to be achieved when a) the building has some margin against either total or partial collapse of the structural system even though significant damage may have occurred that may not be economical to repair; b) major structural elements have not fallen or been dislodged so as to pose a life-safety threat; and c) nonstructural systems or elements that are heavy enough to cause severe injuries either within or outside the building have not been dislodged so as to pose a life-safety threat. [For OSHPD 1 & 4] For buildings in seismic performance categories SPC-3 through 5, the purpose of the division is to provide the immediate occupancy level of seismic performance. At this level, the building and essential nonstructural systems will be reasonably capable of functioning following an earthquake.*

1640A.2 Applicability. *For all state-owned structures, including all buildings owned by the University of California and California State University: The requirements of this division apply wherever the structure is to be retrofitted, repaired, or modified and 1) total construction cost, not including cost of furnishings, fixtures and equipment, or normal maintenance, for the building exceeds 25 percent of the construction cost for the replacement of th eexisting building; or 2) changes in occupancy category; or 3) changes to structural elements reduce the lateral load capacity by more than 5 percent at any story; or 4) structural elements need repair where the damage has reduced the lateral load capacity by more than 10 percent at any story; or 5) changes in live or dead load increase the story shear by more than 5 percent. The changes in Item 1 are cumulative for past alterations to the building that occurred after adoption of this division and did not require the application of this division.*

1640A.2.1 [For OSHPD 1 & 4] *The requirements of this division apply to hospital buildings where Chapter 6, Part 1, Title 24, Building Standards Administrative Code, so requires, wherever the structure is to be retrofitted, repaired, or modified and: 1) there is change in occupancy; or 2) changes to structural elements that reduce or increase the* *lateral load capacity by more than 5% at any story; or, 3) repair of structural elements where the damage has reduced the lateral load capacity by more than 10% at any story; 4) changes in live or dead load that increase the story shear by more than 5%; or 5) where required by Section 1638A or Chapter 6, Part 1, Title 24, Building Standards Administrative Code. The changes in Items 2), 3), and 4) are cumulative for past alterations to the building.*

1640A.2.2 Evaluation required. *If the criteria in Section 1640A.2 apply to the project under consideration, the design professional of record shall provide an evaluation in accordance with Section 1643A to determine the seismic performance of the building in its current configuration and condition. If the structure's seismic performance is evaluated as satisfactory, the peer reviewer(s) (when Method B of Section 1648A is used) concur, and the findings are approved by the enforcement agency, then no structural retrofit is required.*

> ***EXCEPTION:*** *In some cases a technical review and evaluation may be waived under the exception of Section 1648A.1, where the life-safety threat posed by the building is clearly minimal.*

1640A.2.3 [For OSHPD 1] Retrofit required. *Where the evaluation indicates the building does not meet the SPC performance objective of this division, the owner shall take appropriate steps to ensure that the building's structural system is retrofitted in accordance with the provisions of this division. Appropriate steps are either 1) undertake the seismic retrofit as part of the modifications, alterations and/or repairs; or 2) provide a plan, acceptable to the enforcement agent, to complete the seismic retrofit in a timely manner.*

1640A.3 *The modification to any existing building may be prepared in accordance with the requirements for a new building, Chapter 16A, Division IV, Part 2, Title 24, California Code of Regulations 2001 Edition.*

1640A.4 *The requirements of the UBC Appendix Chapter 16A, Sections 1654-1665, are to apply to the use of seismic isolation for the repair, modification or retrofit of an existing structure. When seismic isolation and/or passive energy dissipation is used, the project must have project peer review as prescribed in Section 1649A.*

> ***EXCEPTION:*** *For hospital buildings the requirements of Appendix Chapter 16A, Section 1654A-1665A apply in lieu of those of the UBC for repair, modification or retrofit to existing hospital buildings.*

1640A.5 *Any construction required by this division shall include structural observation by the licensed structural engineer, civil engineer or architect of record who is responsible for the structural design in accordance with Section 1643A.12.*

1640A.6 *Where Method B of Section 1648A is used or is required by Section 1643A.7, the proposed method of building evaluation and design procedures must be accepted by the enforcement agent prior to the commencement of the work.*

1640A.6.1 *The structural system allowances of Chapter 34 do not apply to any building to which Division VI-R applies.*

Section 1641A - DEFINITIONS

1641A.1 *For the purposes of this division certain terms are defined in addition to those in Section 1627A and Chapter 6, Part 1, Title 24, Building Standards Administrative Code, as follows:*

ACTIVE EARTHQUAKE FAULT *is one that has exhibited surface displacement with Holocene time (about 11,000 years) as determined by the California Division of Mines and Geology under the Alquist-Priolo Special Studies Zones Act or other authoritative source, Federal, State or Local Government Agency.*

CODE-COMPLYING ELEMENT *is an element that complies with the Seismic Zone 3 and 4 detailing requirements for elements that are part of the selected lateral-force-resisting system as given in the 1976 or later editions of the UBC [For OSHPD 1, 4, Title 17 and Title 24]. Refer to Section 1645A for specific elements and materials.*

CODE-COMPLYING SYSTEM *is a system that complies with the Seismic Zone 3 and 4 requirements for lateral-force-resisting systems and materials as given in the 1976 or later editions of Title 17 and Title 24.*

DESIGN *is the procedure that includes both the evaluation and retrofit design of an existing element and the design of a new element.*

DESIGN BASIS EARTHQUAKE *is the earthquake ground motion defined in Section 1648A.2.2.1.*

DISTANCE FROM AN ACTIVE EARTHQUAKE FAULT *is measured from the nearest point of the building to the closest edge of an Alquist-Priolo Special Study zone for an active fault, if such a map exists, or to the closest mapped splay of the fault.*

DUCTILE ELEMENT *is an element capable of sustaining large cyclic deformations beyond the attainment of its nominal strength without any significant loss in capacity. Refer to Section 1645A for specific elements and materials.*

ELEMENT *is part of an architectural, electrical, mechanical or structural system.*

ENFORCEMENT AGENT *is that individual within the agency or organization charged with responsibility for agency or organization compliance with the requirements of Division Vi-R.*

ESSENTIALLY COMPLYING STRUCTURAL SYSTEM or ELEMENT *is a lateral-force-resisting system or element that may deviate from but can provide comparable elastic and inelastic cyclic load-deformation behavior as a system or element that complies to the 1976 or later editions of the Uniform Building Code provisions for systems or elements resisting seismic forces. Refer to Section 1645A for specific elements and materials.*

ESSENTIAL LIFE SAFETY *is the retrofit or repair of a structure to a goal of essential life safety as a level of expected structural performance is taken to mean that occupants will be able to exit the structure safely following an earthquake. It does not mean that they will be uninjured or not be in need of medical attention. A structure is presumed to achieve this level of performance where, although significant damage to the structure may have occurred, some margin against either total or partial structural collapse remains, even though damage may not be economical to repair; major structural elements have not become dislodged or fallen so as to pose a life-safety threat; and nonstructural systems or elements, which are heavy enough to cause severe injuries either within or outside the building, have not become dislodged so as to pose a life-safety threat.*

IMMEDIATE OCCUPANCY. *The retrofit or repair of a structure to a goal of immediate occupancy as a level of expected performance is taken to mean the post-earthquake damage state in which only limited structural and nonstructural damage has occurred. The original strength and stiffness of the structure is substantially retained, with minor cracking and yielding of structural elements. Basic access and life-safety systems, including doors, stairways, elevators, emergency lighting, fire alarms, and suppression systems, remain operable, provided that utilities are available. It is expected that occupants could safely remain in the building, although normal use may be impaired and some cleanup, inspection, and limited structural and nonstructural repairs may be required.*

INELASTIC DEMAND RATIO (IDR) *is the ratio of the total load demand on an element to the nominal strength of an element, where load demand is the combination of gravity loads and the un-reduced (by R) elastic response force due to the specified earthquake ground motion.*

LATERAL LOAD CAPACITY *is the capacity as determined either by Method A or Method B of the subject element. A system is the sum of all element capacities acting individually reduced by the* β *factor for the element and meeting the requirements of Section 1646A.2.4. All forms of loading are to consider both displacements in orthogonal directions and torsion.*

LIMITED-DUCTILE ELEMENT *is an element that is capable of sustaining moderate cyclic deformations beyond the attainment of nominal strength without significant loss in strength. The deformation capability is less than that of a ductile element, and these elements do not meet the ductile element criteria of the 1976 or later versions of the UBC. Refer to Section 1645A for specific elements and materials.*

METHOD A *refers to the procedures contained in Sections 1645A-1647A.*

METHOD B *refers to procedures contained in Section 1648A.*

NOMINAL STRENGTH *is the peak capacity of an element using specified material and assembly properties of the applicable materials chapters in Title 24. Examples are the flexural strength of a reinforced concrete beam* M_n *when the maximum concrete strain is* *at 0.003, or the plastic flexural capacity of a steel beam $M_p = ZF_y$ when all fibers in the section are at yield stress F_y and Z is the plastic section modulus. It is also the accepted peak strength from test results.*

***NONDUCTILE ELEMENT** is an element having a mode of failure that results in an abrupt loss of resistance when the element is deformed beyond the deformation corresponding to the development of its nominal strength. Nonductile elements cannot reliably sustain any significant deformation byeond that attained at their nominal strength.*

***PEER REVIEW** refers to the procedures contained in Section 1649A.*

***PROBABLE STRENGTH** is the level of strength of an element likely in as-built or existing materials. For example, in reinforced concrete, it is common that actual steel yield is larger than the specified design value, and therefore probable strength is taken as equal to 1.25 times the nominal strength in flexure.*

***REPAIR** as used in this division means all the design and construction work undertaken to restore or enhance the structural and nonstructural load resisting system participating in the lateral response of a structure that has experienced damage from earthquakes or other destructive events.*

***USABLE STRENGTH or FACTORED STRENGTH** is the product of under strength factor ϕ times the nominal strength in the appropriate material.*

Section 1642A - Symbols and Notations

***1642A.1** The following symbols and notations apply to Division VI-R in addition to those of Section 1628A:*

ϕC_n = *Usable strength or capacity of an element as determined in the materials chapters where ϕ is the strength reduction factor.*

C_w = *Allowable or working stress resistance of an element.*

E = *Seismic load action on an element due to the specified total design base shear.*

H = *The seismic coefficient defined in Section 1643A.8.*

IDR = *Inelastic Demand Ratio.*

IDR_L = *Limit value of the IDR that an element can develop without failure.*

β = *Seismic Load Penalty Factor representing the limited inelastic deformation capability of nonductile and limited-ductile elements with respect to that of ductile elements in a given mode of failure (attainment of nominal strength).*

Ω_o = *Seismic Force Amplification Factor set forth in Table 16A-N.*

Δ_S = *Design Level Response Displacement, which is the total drift or total story drift that occurs when the structure is subjected to the specified seismic forces.*

Δ_M = *Maximum Inelastic Response Displacement, which is the total drift or total story drift given by 0.7 R Δ_S.*

SECTION 1643A - CRITERIA SELECTION

1643A.1 Basis for Evaluation and Design *This section determines what technical approach is to be used for the seismic evaluation and design for existing buildings. For those buildings or portions of buildings for which 1640A.2 requires action, the procedures and limitations for the evaluation of existing buildings and design of retrofit systems and/or repair thereof shall be implemented in accordance with this section. One of three alternative approaches must be used: the first, Method A (Sections 1644A-1647A), is prescriptive and comparable to the Division VI provisions for new structures; the second, Method B (Section 1648A), for complex or potentially hazardous situations is performance based and depends on the independent review of a peer reviewer (Section 1649A); the third is the use of one of the applicable Uniform Code for Building Conservation (UCBC) special procedures given in Section 1643A.1.1.*

1643A.1.1 Special Procedures: *Where there are special prescriptive procedures for the repair and/or retrofit of existing buildings as a part of these regulations, the UCBC, or accepted practice by the Enforcement Agent, these procedures may be used in lieu of the requirements of Chapter 34. The following special prescriptive procedures may be used for their respective types of construction to meet the requirements of this division.*

1. *The UCBC for Seismic Strengthening Provisions for Unreinforced Masonry Bearing Wall Buildings (Appendix Chapter 1).*
2. *The UCBC for Cripple Walls and Anchor Bolts (Appendix Chapter 6).*
3. *The UCBC for Flexible Diaphragm - Rigid Wall Buildings (Appendix Chapter 5).*
4. *The SAC Interim Guidelines for the Evaluation, Repair, Modification, and Design of Welded Steel Moment Frame Structures, FEMA 267, August 1995. The ground motion specifications of this division shall be used when the SAC procedures are applied.*

1643A.1.1.1 *The UCBC for Seismic Strengthening Provisions for Unreinforced Masonry Bearing Wall Buildings (Appendix Chapter 1).*

*[**OSHPD 1: EXCEPTION:** For hospital buildings, the use of unreinforced masonry wall elements is not allowed.]*

1643A.1.1.2 *The UCBC for Cripple Walls and Anchor Bolts (Appendix Chapter 6). [OSHPD 1: Where the requirements of these regulations for new construction are more restrictive, they shall govern. Section A604.4.2 of the UCBC is not adopted.*

EXCEPTION: *Single story wood light frame hospital buildings as defined in Section 2.2.3, Article 2, Chapter 6, Part 1, Title 24, which fail the check Section 5.6.4, Article 5, Chapter 6, Part 1, Title 24, may be upgraded to SPC 2 by seismically retrofitting this deficiency in accordance with the provisions of UCBC for Cripple Walls and Anchor Bolts (Appendix Chapter 6).]*

1643A.1.1.3 *The UCBC for Flexible Diaphragm-Rigid Wall Buildings (Appendix Chapter 5). [OSHPD 1: Where the requirements of these regulations for new construction are more restrictive, they shall govern.]*

1643A.1.1.4 *The SAC Interim Guidelines for the Evaluation, Repair, Modification, and Design of Welded Steel Moment Frame Structures, FEMA 267, August 1995. The ground motion specifications of this division shall be used when the SAC procedures are applied.*

1643A.2 Existing Conditions *The existing conditions and properties of the entire structure must be determined and documented by: thorough inspection; review of all available related construction documents; and performance of necessary testing and investigations. Where samples from the existing structure are taken or in situ tests are performed, they shall be selected and interpreted in a statistically appropriate manner to assure that the properties determined and used in the evaluation or design are representative of the conditions and structural circumstances likely to be encountered in the structure as a whole.*

The entire load path of the lateral force resisting system shall be determined, documented, and evaluated. The load path includes all the horizontal and vertical elements participating in the structural response such as diaphragms, diaphragm chords, diaphragm drags, vertical lateral force resisting system (walls, frames, braces, etc.), foundations, and the connection between the elements of the load path.

1643A.3 Site Geology and Soil Characteristics. *Soil profile shall be assigned in accordance with the requirements of Section 1629A.3.*

1643A.4 Occupancy Categories. *For purposes of earthquake–resistant design, each structure shall be placed in one of the occupancy categories in accordance with the requirements of Section 1629A.2. [OSHPD 1: For hospital buildings, I=1.0 for category SPC-2 and I=1.5 for SPC-3 through SPC-5, as determined in accordance with the requirements of Chapter 6, Part 1, Title 24, Building Standards Administrative Code].*

1643A.5 Configuration Requirements. *Each structure shall be designated as being structurally regular or irregular in accordance with the requirements of Section 1629A.5.*

1643A.6 Selection of the Design Method. *The requirements of Method B (Section 1648A) may be used for any existing building.*

1643A.7 *The requirements of Method A (Sections 1644A-1647A) may be used except under the following conditions, where Method B [for OSHPD 1 & 4] or Special Procedures as defined in Section 1643A.1.1 must be used.*

1643A.7.1 *When the building contains prestressed or post-tensioned structural elements (beams, columns, walls, or slabs) or contains precast structural elements, (beams, columns, walls or flooring systems).*

1643A.7.2 *When the building is classified as irregular in vertical or horizontal plan application of Table 16A-L or 16A-M unless the irregularity is demonstrated not to affect the seismic performance of the building;*

> ***EXCEPTION:*** *If the retrofit design removes the configurational attributes that caused the building to be classed as irregular, then Section 1643A.7.2 does not apply and Method A may be used.*

1643A.7.3 *For any building which has an importance factor I greater than 1.00, Table 16A-K.*

> ***EXCEPTIONS:*** *1. For hospital buildings, Method A may be used for retrofitting SPC 1 structures to SPC-2 structures where: a) the building has four or fewer stories, but with continuous diaphragms; or, b) where the building is of Type V construction; or, c) located in Zone 3.*
> *2. For hospital buildings, Method A may be used for retrofit or repair of nonstructural components and systems.*

1643A.7.4 *For any building using undefined or hybrid structural systems.*

1643A.7.5 *When passive or active energy absorption systems are used in the retrofit or repair, either as part of the existing structure or as part of the modifications.*

1643A.7.6 *When the height of the structure exceeds 240 feet (73 152 mm).*

1643A.8 Seismic Hazard Factor *The Seismic Hazard Factor H shall be determined according to the following procedure.*

1643A.8.1 *When the Importance Factor, I, is equal to 1 then H is equal to:*

> ***[For OSHPD 1] EXCEPTION:*** *For hospitals this value of H may be used where I is equal to 1.0 if the assigned performance category is SPC-2.*

1643A.8.1.1 *Three-quarters (0.75) when the seismic coefficients C_a and C_v are determined from Table 16A-Q and Table 16A-R.*

1643A.8.1.2 *Unity (1.0) when the seismic coefficients C_a and C_v are determined from a 5 percent damped acceleration response spectrum with a 20% probability of exceedance in 50 years determined from a probabilistic seismic hazard analysis for the specific site. The smoothed response spectrum value at the period of 0.3 seconds provides the value of 2.5 C_a g and the spectrum at 1.0 seconds provides the value of C_v g, where g is the gravity constant.*

> ***EXCEPTIONS:*** *1. When there has been a Section 1643A.8.1.2 analysis performed, the Enforcement Agent may accept the results of this prior study on a case by case basis.*
> *2. The results of a community-wide probabilistic seismic analysis (Section 1643A.8.1.2) may be used when the responsible Enforcement Agent has accepted a probabilistic seismic hazard study for the jurisdiction to determine the value required by 1643A.8.1.2 for sites within the jurisdiction, provided that the study on which it is based was accepted by reviewers, who were selected and charged consistent with the professional requirements of Section 1649A.*

1643A.8.2 *Otherwise, the H value is equal to unity (1.0), and the seismic coefficients C_a and C_v may be determined either from Table 16A-Q and Table 16A-R or from a 5 percent damped acceleration response spectrum with a 10% probability of exceedance in 50 years determined from a probabilistic seismic hazard analysis for the specific site.*

> ***EXCEPTIONS:*** *1. Exception of Section 1643A.8.1.2 applies.*
> *2. For Section 1643A.8.2, when the importance factor, I, is greater than 1 and less than or equal to 1.25, then I may be set equal to 1 for subsequent load determinations if the seismic coefficients*

C_a and C_v are determined from a 5 percent damped response spectrum with a 10% probability of exceedance in 100 years determined from a probabilistic analysis for the specific site.

1643A.9 Capacity Requirements. *All elements of the lateral-force-resisting system must have the capacity to resist the seismic demand. Any element not having this capacity shall have its capacity increased by modifying or supplementing its capacity so that it exceeds the demand, or the demand reduced to less than the existing capacity by making other modifications to the structural system.*

EXCEPTIONS: *1. An element's usable strength capacity may be less than that required by the specified seismic load combinations if it can be demonstrated that the associated reduction in seismic performance of the element or its removal due to the failure does not result in a structural system in which there is a life-safety hazard due to the loss of support of gravity loads; a laterally unstable structure; or falling structural or nonstructural elements or parts thereof. If this exception is taken for an element, then it cannot be considered part of the primary lateral-load-resisting system.*

2. The load transferred from an adjoining element to a given element need not exceed the probable strength 1.25 C_n of the adjoining element, given that the assembly remains stable. For elements where the resistance is expressed in terms of the allowable or working stress method, the usable strength ϕC_n may be determined using an allowable stress increase of 1.70, or may be established by acceptable published factors for a given material or element, or by the use of appropriate available test data and the applicable principles of mechanics.

3. This requirement does not apply to a mechanical penthouse when its floor area is less than one third of that of the immediately lower floor.

1643A.10 New Elements. *All new elements shall either be "code-complying or ductile" or "limited-ductile," and shall be selected and designed to have compatible force-deformation performance with existing elements and non-structural components.*

EXCEPTION: *The use of "nonductile" elements is allowed if the particular material provides the only means of ensuring compatible performance without detrimental interaction effects on the existing element material. Code-complying or essentially code-complying details shall be used where possible.*

1643A.11 Deformation Compatibility. *The compatibility of the deformation characteristics of all elements activated in the response shall be considered, as well as the configuration of the structural and nonstructural systems; the continuity, or lack thereof, of load paths; the redundancy, if any, of these load paths; and the physical condition of the materials and elements.*

1643A.12 Structural Observation.

1643A.12.1 *Structural observation as used in this division shall mean visits to the project site by the responsible design professional to observe existing conditions and to review the construction work for general compliance with approved plans, specifications and applicable structural regulations. Such visits shall occur at significant construction stages and at the completion of the structural retrofit. Structural observation shall be provided in Seismic Zones 3 and 4 for all structures regulated by this division. Highrise construction requires an interim progress report each month in addition to observation reports for the significant construction stages. The owner shall directly employ the engineer or architect, or their designee, responsible for the structural design to perform structural observation.*

After each visit, the structural observer shall report in writing on the general conformity of the work to the approved plans and note any observed deficiencies to the owner's *representative, project inspector, contractor and the enforcement agent. The structural observer shall notify the enforcement agent in writing in a timely manner how the structural deficiencies are to be corrected. If satisfactory resolution of the deficiency is not obtained, the enforcement agent shall be notified for any necessary action.*

At the conclusion of construction, the structural observer shall submit to the enforcement agent and the owner a final written statement that the required site visits have been made, that the work, to the best of the structural observer's knowledge and belief, is or is not in general conformity to the approved plans and that the observed structural deficiencies have been resolved and/or listing those that, to the best of the structural observer's knowledge and belief, have not been satisfactorily corrected.

1643A.12.1.1 *The requirement for structural observation shall be noted and prominently displayed on the front sheet of the approved plans and incorporated into the general notes on the approved plans.*

1643A.12.1.2 Preconstruction Meeting. *A preconstruction meeting is mandatory for all projects which require structural observation. The meeting shall include, but is not limited to, the design engineer or architect, structural observer, general constructor, affected subcontractors, the project inspector and a representative of the enforcement agency (designated alternates may attend if approved by the structural observer). The structural observer will schedule and coordinate this meeting.*

The purpose of the meeting is to identify and clarify all essential structural elements and connections that affect the lateral and vertical load systems and review scheduling of the required observations for the project's structural system retrofit.

1643.12.2 [For OSHPD] Structural observation, testing and inspections.
Construction testing, inspection and observation requirements shall be as set forth in Chapter 7, Article 4, Part 1, Title 24, Building Standards Administrative Code, Chapter 17A, and the testing and inspection requirements of Chapters 18A through 24A.

1643A.13 Temporary Actions. *When compatible with the building use, and the time phasing for both use and the retrofit program, temporary shoring or other structural support may be considered. Temporary bracing, shoring and prevention of falling hazards can offer an affordable means of qualifying for the exception in Section 1644A.4.1.1 that allows inadequate capability in some existing elements as long as life safety can be provided.*

SECTION 1644A - METHOD A

1644A.1 General. *Structures shall be designed for seismic forces coming from any horizontal direction. The design seismic forces may be assumed to act nonconcurrently in the direction of each principal axis of the structure, except as required by Section 1646A.1.4. Seismic dead load, W, is the total dead load and applicable portions of other loads listed below.*

1644A.1.1 *In storage and warehouse occupancies, a minimum of 25 percent of the floor live load shall be applicable.*

1644A.1.2 *Where a partition load is required in the floor design, a load of not less than 10 pounds per square foot (psf) (0.48kN/m^2) shall be included.*

1644A.1.3 *Design snow loads of 30 pounds per square foot (psf) (1.44 kN/m^2) or less need not be included. Where design snow loads exceed 30 psf (1.44 kN/m^2) the design snow load shall be included, but may be reduced up to 75 percent where consideration of siting, configuration and load duration warrant when approved by the enforcement agency.*

1644A.1.4 *Total weight of permanent equipment shall be included.*

1644A.2 *Determine the most applicable complying or essentially complying structural system as described in Section 1629A.6. All elements that are capable of providing significant resistance to the actions of lateral forces shall be included in the system.*

> ***EXCEPTION:*** *Elements made of noncomplying materials and/or details, and nonstructural components may be omitted from the system provided that their rigidity, capacity and load-deformation behavior are established for use in the investigation of the effects of these elements on the structural system as required by Sections 1646A.2.4 and 1646A.2.4.1.*

1644A.2.1 *Classify each element included in the assigned structural system and foundation as being either "ductile," "limited-ductile," or "nonductile" according to its relative compliance with required provisions and/or its ability to deform beyond the nominal strength level without an abrupt or significant loss of resistance.*

All elements shall be considered nonductile if they do not comply or do not essentially comply with the requirements for ductile elements. The limited-ductile classification must be established by related empirical data and analysis, or by meeting the requirements given in Section 1645A.

Section 1645A provides a listing of code dates and extra provisions that apply for given elements and materials to qualify for the "code-complying or ductile" classification. Section 1645A also provides the procedures and criteria that apply for the "limited-ductile" and "nonductile" classification. The stiffness and nominal strength or capacity C_n of each element shall be determined for each possible mode of failure of the element.

1644A.2.3 Modeling requirements. *The mathematical model of the physical structure shall comply with Section 1630A.1.2.*

1644A.3 General. *Structural systems shall be classified with the requirements of Section 1629A.6 as one of the types listed in Table 16A-N and defined in this section. The system selected for an existing building to be most appropriate for a given existing building may contain noncomplying elements and/or elements which essentially comply to the required provisions and details for that system provided that all the non-complying and essentially complying elements have been properly classified as "non-ductile," "limited-ductile," or "ductile" and the corresponding β values are applied to their seismic load.*

1644A.3.1 *The system R value shall be taken as 4.5 for all existing structural systems except for the following conditions:*

1644A.3.1.1 *R may be taken as 5.5 if the system constructed meets the requirements for a Building Frame System as defined in Section 1629A.6.3.*

1644A.3.1.2 *For structures designed to meet all of the seismic provisions of the 1976 or later editions of the UBC, R may be taken as appropriate R value given in Table 16A-N for the corresponding basic structural system.*

1644A.4 Static Force Procedures.

1644A.4.1 Design base shear. *The total design base shear in a given direction shall be determined from the following formula:*

$$V = \frac{HC_vIW}{RT} \qquad (44A\text{-}1)$$

The total design base shear need not exceed the following:

$$V = \frac{2.5\,HC_aIW}{R} \qquad (44A\text{-}2)$$

The total design base shear shall not be less than the following:

$$V = 0.11\,HC_aIW \qquad (44A\text{-}3)$$

In addition, for Seismic Zone 4, the total base shear shall also not be less than the following:

$$V = \frac{0.8\,HZN_vIW}{R} \qquad (44A\text{-}4)$$

1644A.4.1.1 Strength Basis for Evaluation and Design. *Elements subject to seismic force action E due to the specified base shear V shall have the usable strength capacity ϕC_n to resist the following load combinations:*

1. For the case where actions D, L and E are all in the same sense,

$$\Phi C_n = 1.05D + 0.25L + \beta E \qquad (44A\text{-}5)$$

where the live load L is the realistic live load, but shall not be less than the design load specified for the occupancy.

2. For the case where the action E is opposite to the sense of D,

$$\Phi C_n = \beta E - 0.9D \qquad (44A\text{-}6)$$

In the load combinations (44A-5) and (44A-6), the seismic load penalty factor β represents the limited inelastic deformation capability of nonductile and limited-ductile elements for an associated mode of failure. Values of β for specific types of elements and modes of failure are given in Section 1645A.

EXCEPTION: *See Exceptions 1 and 2 in Section 1643A.9.*

1644A.4.1.2 Allowable or Working Stress Basis for Evaluation and Design. *Allowable or working stress method along with the one third allowable stress increase as permitted by Section 1612A3.2 may be used to establish the allowable or working stress capacity C_w of an element. The capacity C_w shall meet the following load combination requirements:*

3. For the case where the actions D, L, and E are all in the same sense,

$$C_w = D + L + \frac{\beta E}{1.4} \qquad (44A\text{-}7)$$

4. For the case where the action E is opposite to the sense of D,

$$C_w = \frac{\beta E}{1.4} - 0.9D \qquad (44A\text{-}8)$$

EXCEPTION: *Section 1644A.4.1.2 may not be used for reinforced concrete.*

1644A.4.2 Structure period. *The value of T shall be determined in the same manner as for a new building contained in Section 1630A.2.2.*

1644A.5 Combinations of Structural Systems - General. *Where combinations of structural systems are incorporated into the same structure, the same requirements shall be satisfied as for a new building of Section 1630A.4 shall be satisfied.*

1644A.6 Vertical Distribution of Force. *The total force shall be distributed over the height of the structure in conformance with the requirements of Section 1630A.5 for new buildings.*

***1644A.7 Horizontal Distribution of Shear**. The design story shear shall be distributed over the height of the structure in conformance with the requirements of Section 1630A.5 for new buildings.*

***1644A.8 Horizontal Torsional Moments.** Provisions shall be made for the increased shears resulting from horizontal torsion where diaphragms are not flexible. The most severe load combination for each element shall be considered for design in conformance with the requirements of Section 1630A.7 for new buildings.*

1644A.9 Overturning.

***1644A.9.1 General.** Every structure shall be designed to resist the overturning effects caused by earthquake forces specified in Section 1630A.5. At any level, the overturning moments to be resisted shall be determined using those seismic forces (F_t and F_x) which act on levels above the level under consideration. At any level, the incremental changes of the design overturning moment shall be distributed to the various resisting elements in the manner prescribed in Section 1630A.5. Overturning effects on every element, wherever possible, shall be carried down directly in a linear path to the foundation. See load combinations in Section 1644A.4.1.1 and 1644A.4.1.2 for combining gravity and seismic forces.*

***1644A.9.2 Seismic Zones 3 and 4.** In Seismic Zones 3 and 4, where a lateral-load–resisting element is discontinuous, such as for vertical irregularity Type 4 in Table 16A-L or plan irregularity Type 4 in Table 16A-M, columns supporting such elements shall have the strength to resist the axial force resulting from the following load combinations, in addition to all other applicable load combinations:*

$$\phi C_n = D + 0.8\,L + \Omega_o \beta E \tag{44A-9}$$

$$\phi C_n = \Omega_o B E - 0.9\,D \tag{44A-10}$$

$\Omega_o \beta E$ *in Formulas (44A-9) and (44A-10) need not exceed RE.*

***1644A.9.2.1** The axial forces in such columns need not exceed the resultant of the probable strengths of other elements of the structure that transfer such loads to the column.*

***1644A.9.2.2** Such columns shall be capable of carrying the above-described axial forces without exceeding the usable axial load capacity (ϕC_n) of the column. For designs using working stress methods, this capacity may be determined using an allowable stress increase of 1.7 or acceptable published factors for a given material or element.*

> ***EXCEPTION:** See Exceptions 1 and 2 in Section 1643A.9.*

1644A.9.2.3 Columns.

1644A.9.2.3.1 *Such columns shall either resist the above-described axial forces without exceeding the usable axial capacity (ϕC_n), or shall meet the following detailing and member limitations:*

1. *Chapter 19, Section 1921A.4, for concrete, and Chapter 22, Sections 2210A, 2211.4 and 2211.5, for steel in structures in seismic Zones 3 and 4, except for welded steel moment connections where the current SAC Guidelines for columns apply.*
2. *Chapter 19, Section 1921.8, for concrete, and Chapter 22A, Divisions I and IX, special provisions for developing plastic hinges at ultimate loading, for steel in structures in Seismic Zone 2.*

1644A.9.2.3.2 [For OSHPD 1 & 4] *In order to qualify for a β value equal to 1.0, such columns shall meet the following detailing and member limitations:*

1. *Chapter 19A, Section 1921A.4, for concrete, and Chapter 22A, Section 2210A, 2211.4, Items 4 and 5, for steel in structures in Seismic Zones 3 and 4, except for welded steel moment connections where the SAC Interim Guidelines for the Evaluation, Repair, Modification, and Design of Welded Steel Moment Frame Structures, FEMA 267, August, 1995, provisions for columns apply.*

1644A.9.2.4 *Transfer girders that support such columns or that provide support for the discontinuous lateral-load-resisting element shall resist the above-described axial forces or support reactions without exceeding the capacity ϕC_n for each mode of failure. For this case, the β factor shall correspond to the properties of the girder.*

1644A.9.3 At Foundation. *See Section 1809A.4 for overturning moments to be resisted at the foundation soil interface. The foundation soil interface shall be capable of resisting the following load combinations on the allowable stress basis of Section 1809A.2 and Table 18A-1-A, and other load combinations need not apply:*

$$D + L + \frac{E}{1.4} \qquad \textit{(44A-11)}$$

$$\frac{E}{1.4} - 0.9D \qquad \textit{(44A-12)}$$

*In order to determine the strength design basis loads for the elements of the foundation structure, the soil pressures and pile or caisson reactions due to these load combinations shall be load factored by 1.4. The resulting bending moments, shears, and axial loads on the sections of the foundation structure are to be factored by the appropriate β value and shall be resisted by the corresponding usable strength ϕC_n of the section. If piles or caissons are required for overturning moment tension resistance due to the load combination (*44A-12*), then the minimum tensile load-carrying resistance ϕC_n shall be E/14.*

1644A.10 Drift and Story Drift Limitation. *Drift or horizontal displacements of the structure shall be computed where required by this code. For both Allowable Stress Design and Strength Design, the Maximum Inelastic Response Displacement, Δ_M , of the structure caused by the Design Basis Ground Motion shall be determined in accordance with this section. The drifts corresponding to the design seismic forces of Section 1644A.4.1, Δ_S , shall be determined in accordance with Section 1644A.10.1. To determine Δ_M , these drifts shall be amplified in accordance with Section 1644A.10.2.*

1644A.10.1 Determination of Δ_S . *A static, elastic analysis of the lateral force-resisting system shall be prepared using the design seismic forces from Section 1644A.4.1 and 1644A.6. The mathematical model shall comply with Section 1644A.2.3. The resulting deformations, denoted as Δ_S shall be determined at all critical locations in the structure. Calculated drift shall include translational and torsional deflections.*

1644B.10.2 Determination of Δ_M. *The Maximum Inelastic Response Displacement, Δ_M , shall be computed as follows:*

$$\Delta_M = 0.7\, R\, \Delta_S \qquad (44A\text{-}13)$$

1644A.10.3 Story drift defined. *Story drift is the displacement of one level relative to the level above or below using the Maximum Inelastic Displacement, Δ_M , at each level.*

1644A.10.4 Story drift limits. *Calculated story drift using Δ_M shall not exceed 0.025 times the story height for structures having a fundamental period of less than 0.7 second. For structures having a fundamental period of 0.7 second or greater, the calculated story drift shall not exceed 0.020 times the story height.*

> ***EXCEPTION:*** *These story drift limits may be exceeded when it is demonstrated that greater drift can be tolerated by both structural elements and nonstructural elements that could affect life safety for buildings in seismic performance categories SPC-1 and SPC-2, and life safety and continued operation in SPC-3 through SPC-5 buildings.*

1644A.11 PΔ Effects. *The resulting member forces and moments and the story drifts induced by PΔ effects shall be considered in the evaluation of overall structural frame stability and shall be evaluated using the specified design forces and their corresponding displacements Δ_S. PΔ need not be considered when the ratio of secondary moment to primary moment does not exceed 0.10; the ratio may be evaluated for any story as the product of the total dead, floor live load, and snow load above the story times the seismic drift Δ_S in that story divided by the product of the seismic shear in that story times the height of that story. In Seismic Zones 3 and 4, PΔ need not be considered where the story drift ratio does not exceed 0.02/R.*

1644A.12 Vertical Component. *The following requirements apply in Seismic Zones 3 and 4 only. Horizontal cantilever components shall have the usable strength capacity ϕC_n to resist (0.7) $H\, C_a\, W_p$, or have an allowable or working stress capacity C_w to resist (0.5) $H\, C_a\, W_p$. The value of the seismic hazard factor H shall be as prescribed by Section 1643A.8 according to the occupancy and conditions of the building.*

1644A.13 Lateral Force on Elements of Structures, Nonstructural Components and Equipment Supported by Structures. *Elements of structures and their attachments,* *permanent nonstructural components and their attachments, and the attachments for permanent equipment supported by a structure shall be designed to resist the total design seismic forces prescribed in Section 1644A.13.1. Attachments for floor- or roof-mounted, but not suspended, equipment weighing less than 400 pounds (181 kg), and furniture need not be designed.*

Attachments shall include anchorages and required bracing. Friction resulting from gravity loads shall not be considered to provide resistance to seismic forces.

When the failure of the lateral-force-resisting anchorage, bracing or connection of nonrigid equipment would cause a life hazard, such elements shall be designed to resist the seismic forces prescribed in Section 1644A.13.1.

When allowable design stresses and other acceptance criteria are not contained in or referenced by this code, such criteria shall be obtained from approved national standards.

1644A.13.1 Design for Total Lateral Force.

1644A.13.1.1 *The total design lateral seismic force, $F_{p,}$ shall be determined from the following formula:*

$$F_p = 4.0 H C_a I_p W_p \qquad (44A\text{-}14)$$

Alternatively, F_p may be calculated using the following formula:

$$F_p = a_p H C_a/R_p (1 + 3h_x/h_r) W_p \qquad (44A\text{-}15)$$

Except that:

F_g shall not be less than $0.7 H C_a I_p W_p$ and
Need not be more than $4 H C_a I_g W_g$. *(44A-16)*

Where:

h_x = the element or component attachment elevation with respect to grade, h_x shall not be taken less than 0.0.

h_r = the structure roof elevation with respect to grade. The value of h_x/h_r need not exceed 1.0.

a_p = is the in-structure Component Amplification Factor that varies from 1.0 to2.5.

A value for a_p shall be selected from Table 16A-O.

R_p is the Component Response Modification Factor that shall be taken from Table 16A-0, except that R_p for anchorages shall equal 1.5 for shallow expansion bolts, shallow chemical anchors, or shallow cast-in-place anchors. Shallow anchors are those with an embedment length-to-diameter ratio of less than 8. Where anchorage is constructed of nonductile materials, or has nonductile behavior, or the component is attached with an adhesive surface joint, R_p shall equal 1.0. The β factor may be taken as 1.0 for anchorages requiring R_p equal to 1.0, 1.5 or 3.0.

The design lateral forces determined using Formula (44A-14) or (44A-15) shall be distributed in proportion to the mass distribution of the element or component.

Forces determined using Formula (44A-14) or (44A-15) shall be used to design members and connections that transfer these forces to the seismic-resisting systems. Members and connections shall use the load combinations and factors specified in Section 1644A.4.1.1 or 1644A.4.1.2. The member or connection actions due to F_p are the earthquake load E to be used in the load combinations.

> ***EXCEPTION:*** *Where a probabilistic hazard analysis has been performed, the Exception 2 of Section 1643A.8.2 may be applied for the term HI_p in Formula 44A-11.*

To determine the out-of-plane loading for elements such as walls or wall panels that have points of attachment at two or more different elevations, the following procedure may be used. For the vertical span of the element having a unit weight W_p between two successive attachment elevations h_x and h_{x+i} evaluate the force coefficients F_a /W_a at each of the two points, observing the minimum and maximum limits, and compute the average of the two values. The resulting average coefficient times the unit weight W_p provides the distributed seismic load for the span between the attachment points, and this load may be extended to the top of any wall parapet above the roof attachment point at h_r.

1644A.13.1.2 [For OSHPD 1 & 4] *Critical nonstructural components and systems, as defined in Table 11.1, Chapter 6, California Building Standards Administrative Code, and all components and systems in buildings in seismic performance categories SPC-3 through SPC-5 shall meet the requirements for new buildings, Section 1632A. All other elements of structures, nonstructural components and equipment supported by structures shall comply with provisions of Section 1645A.7 and this section.*

[For OSHPD] *The total design lateral force, F_p, shall be determined from the following formula:*

$$F_p = \beta H C_a I_p W_p \qquad (44A\text{-}14)$$

Alternatively, F_p may be calculated using the following formula:

$$F_p = \beta a_p H C_a (1 + 3h_x / h_r) W_p / R_p \qquad (44A\text{-}15)$$

Except that:

> *Fp shall not be less than $0.7\beta HC_aI_pW_p$ and need not be more than $4\beta HC_aI_pW_p$.* *(44A-16)*

Where:

> *β is the value for the connection, not the element to which it is attached. The values of β for connections, bracing and materials shall be prescribed in Section 1645A.7.2.*
> *I_p is the value used for the structure selected from Table 16A-K.*
> *h_x is the element or component attachment elevation with respect to grade. h_x shall not be taken less than 0.0.*
> *h_r is the structure roof elevation with respect to grade. The value of h_x/h_r need not exceed 1.0.*

a_p is the in-structure Component Amplification Factor that varies from 1.0 to 2.5. A value for a_p shall be selected from Table 16A-O.

R_p is the Component Response Modification Factor that shall be taken from Table 16A-O, except that R_p for anchorages shall equal 1.5 for shallow expansion bolts, shallow chemical anchors or shallow cast-in-place anchors. Shallow anchors are those with an embedment length-to-diameter ratio of less than 8. Where anchorage is constructed of nonductile materials, or has nonductile behavior, or the component is attached with an adhesive surface joint, R_p shall equal 1.0.

The design lateral forces determined using Formula (44A-14) or (44A-15) shall be distributed in proportion to the mass distribution of element or component.

Forces determined using Formula (44A-14) or (44A-15) shall be used to design members and connections that transfer these forces to the seismic-resisting systems. Members and connections shall use the load combinations and factors specified in Section 1644A.4.1.1 or 1644A.4.1.2. The member or connection actions due to F_p are the earthquake load E to be used in the load combinations.

***EXCEPTION:** Where a probabilistic hazard analysis has been performed, Exception 2 of Section 1643A.8.2 may be applied for the term HI_p in Formula (44A-11).*

To determine the out-of-plane loading for elements such as walls or wall panels that have points of attachment at two or more different elevations, the following procedure may be used. For the vertical span of the element having a unit weight w_p between two successive attachment elevations h_x and h_{x+i} evaluate the force coefficients F_p/W_p at each of the two points, observing the minimum and maximum limits, and compute the average of the two values. The resulting average coefficient times the unit weight w_p provides the distributed seismic load for the span between the attachment points, and this load may be extended to the top of any wall parapet above the roof attachment point at h_r.

SECTION 1645A—PROCEDURES FOR THE CLASSIFICATION OF ELEMENTS INTO THE DUCTILE, LIMITED-DUCTILE, AND NONDUCTILE CATEGORIES

***1645A.1 General.** All elements will be classified as either being “ductile, limited-ductile, or nonductile.” The purpose of this section is to provide the procedures and guidelines necessary for this classification and assignment of β values. The general requirements for all materials are listed below and will be followed by the specific requirements for each material.*

***1645A.1.1 Ductile Category.** A ductile element is one that complies with the definition of ductile. Code-complying elements shall be classified as ductile, except as noted in Section 1644A.9.2.3. Otherwise, a rational analysis, as described in the nonductile category below, may be used to justify the use of the ductile classification.*

1645A.1.2 Non-Ductile Category. *Any element that does not comply with the code-compliant definition shall be classified as non-ductile; except for the case where it either complies with the specific provisions of Section 1645A required for the limited-ductile category, or a rational analysis based on the principles of mechanics, related research and test results can demonstrate that it has the cyclic inelastic deformation behavior required for the limited-ductile or ductile categories.*

1645A.1.3 Limited-Ductile Category. *An element that does not qualify as ductile, but does comply or essentially complies with the specific material limited-ductile provisions of Section 1645A, may be classified as limited-ductile. Otherwise, a rational analysis as described in the nonductile category above may be used to justify the use of the limited-ductile classification.*

1645A.2 *For each element and loading condition, a β value is assigned that represents the expected load-deflection behavior of the element during the full earthquake loading of the element, including repeated, reversing load. β values that are significantly different from those given in Section 1645A must receive the acceptance of the enforcement agency when they are used in the analysis and design.*

1645A.2.1 *Sections 1645A.3 through 1645A.6.2 provide reference values for selected elements and loading conditions; these β values are to be used as guidance for the assignment of values for conditions and elements not listed by comparison of expected performance to that expected for listed elements.*

1645A.2.2 *Alternative β values to those listed may be used where experimental results, coupled with rational analysis, lead to the conclusion that a different β value better represents the behavior of a given element and its conditions. Such interpretation and analysis shall be subject to the review and approval of the enforcement agent and shall consider the following items:*

1. *The effects of cyclic load reversals representative of seismic loading beyond the strength level of the element, considering the specific nature of the loading used in the test, especially whether essentially static or dynamic.*
2. *The size or scale effect of the test data, along with the compatibility of the test specimen details with those of the existing element.*
3. *The sample size of the test program and range of related test variables necessary to reasonably define behavior.*

1645A.3 Reinforced Concrete. *Reinforced concrete is considered to be any combination of concrete with steel reinforcing that can develop the compressive and tensile properties of the respective materials. The procedures and provisions for the classification of ductile, limited-ductile and nonductile elements are given in Sections 1645A.3.1 through 1645A.3.1.4. The corresponding β values are given in Table 16A-R-1.*

1645A.3.1 Reinforced concrete frame elements.

1645A.3.1.1. *Any frame element in conformance with the requirements of 1976 UBC Section 2626 or later editions (Section 1921A.1 through 1921A.5 for Seismic Zones 3 and 4) may be classified as ductile and the β value taken as 1.0.*

> ***EXCEPTIONS:*** *1. Hooked bar development length shall comply with Section 1921A.5.4 to qualify the bar anchorage as ductile.*
>
> *2. For a column to be classified as ductile, no more than one-third of the columns in a story level of its frame-line may have the weak column-strong beam condition; otherwise, each column in the story level frame-line shall be classified as no more than limited ductile.*

1645A.3.1.2. *Any frame element in essential conformance with the requirements of Section 1921A.8 or equivalent requirements of earlier editions, shall be classified as limited ductile and assigned a β value equal to or greater than that given in Table 16A-R-1.*

1645A.3.1.3. *Any column members in essential compliance with the requirements of Section 1921A.7.2 and 1921A.7.3 shall be classified as limited-ductile and assigned a β value equal to or greater than that given in Table 16A-R-1.*

1645A.3.1.4. *Any element not meeting the requirements of Section 1645A.3.1.1, 1645A.3.1.2 or 1645A.3.1.3 shall be classified as non-ductile, with corresponding β value equal to or greater than that given in Table 16A-R-1, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:*

1. *Reinforcing bar lap splice length, cover, and ties.*
2. *Pile-to-footing connection resistance to tension due to overturning moment. (Section 1644A.9.3).*
3. *Footing flexural and shear capacity.*
4. *Column ties for both shear resistance and concrete confinement.*
5. *Positive Moment tension bar pullout or slab flexural failure. (Section 1646A.1.3.2)*
6. *Negative moment hook pullout.*
7. *Stirrups for both shear resistance and concrete confinement.*
8. *Non-continuous longitudinal steel leaving sections with weakness in flexural and shear resistance. (Section 1921.8.4.1)*
9. *Joint shear reinforcing and confinement.*
10. *Weak column-strong beam condition. (Sections 1645A.3.1.1, Exception 2, and 1921A.4.2.2).*
11. *Slab punching shear.*
12. *Short or captive column.*
13. *The shear capacity of columns.*

1645A.3.2 Shear Walls and Diaphragms.

1645A.3.2.1 *Any shear wall or diaphragm in conformance with the requirements of the 1976 UBC Section 2626 or later editions (Section 1921.6) may be classified as ductile and the β value taken as 1.0.*

> ***EXCEPTION:*** *A shear wall that essentially meets the boundary zone requirements of Section 1921.6.6 may be classified as ductile.*

1645A.3.2.2 *Any shear wall or diaphragm in conformance with 1976 UBC Section 2614 may be classified as a limited-ductile element and assigned a β value equal to or greater than that given in Table 16A-R-1.*

1645A.3.2.3 *Any wall element not meeting the requirements of Section 1645A.3.2.1 or 1645A.3.2.2 shall be classified as nonductile, with corresponding β value equal to or greater than that given in Table 16A-R-1, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:*

1. *Dowel and reinforcing bar lap splice length, cover and ties.*
2. *Boundary element or boundary zone confinement ties.*
3. *Horizontal shear steel and its anchorage in boundary element or boundary zone.*
4. *Location and characteristics of construction joints.*
5. *Relative stiffness and friction resistance of soil-footing interface to determine if the effects of foundation rotation and/or horizontal slip need to be included in the analytical model (Section 1646A.1.3.4).*
6. *Diaphragm drag or collector elements and connection of diaphragm to wall or braced frame (Sections 1646A.1.3.3 and 1646A.1.3.4).*
7. *Spandrel capacity to resist flexure and vertical shear.*
8. *Pile-to-footing connection resistance to tension due to overturning moment (Section 1644A.9.3).*

1645A.3.2.4 *Any diaphragm element not meeting the requirements of Section 1645A.3.2.1 or 1645A.3.2.2 shall be classified as nonductile, with corresponding β value equal to or greater than that given in Table 16A-R-1, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:*

1. *Thickness of slab and positioning of reinforcing.*
2. *Shear connection to walls.*
3. *Shear reinforcing.*
4. *Reinforcing around openings.*
5. *Chord element.*
6. *Drag or collector elements.*

1645A.4 Masonry.

1645A.4.1 Ductile or Code Complying. *Any element in essential conformance with the seismic requirements of Chapter 21A, Sections 2106A.1.12.4 and 2108A.2.3.8, may be classified as ductile and the β value taken as 1.0.*

> ***EXCEPTION:*** *Any shear wall pier and spandrel element having height or clear span to depth ratios greater than 2 shall comply with Section 2108A.2.6 (Wall Frames), to be classified as ductile; otherwise, it shall be classified as a limited-ductile element with β = 2.5 or greater.*

1645A.4.2 Limited-Ductile. *Any masonry element in essential conformance with the 1994 UBC Sections 2106.1.12.3 (special provisions for Seismic Zone 2), and 2108.2.3.8 (seismic design provisions), shall be classified as limited ductile and assigned a β value equal to or great than 2.5 for all modes of failure.*

1645A.4.3 Nonductile. *Systems and elements that do not comply with Section 1645A.4.1 or 1645A.4.2 shall be classified as nonductile, with a corresponding β value equal to or greater than 4.5 for all modes of failure, except where Section 1645A.2 allows use of another value, Section 1645A.2.2 analysis shall consider at a minimum:*

Wall elevation:

1. *Horizontal and vertical reinforcing.*
2. *Reinforcing at edges of wall openings.*
3. *Slenderness proportions of wall piers and spandrels.*
4. *Height-to-thickness ratio of wall.*
5. *Special reinforcing for slender piers.*
6. *Spandrels and openings.*
7. *Diaphragm connections.*
8. *Quality of dry-pack mortar joints and grouting of shear friction dowels at the horizontal joint between the top of masonry walls and adjoining reinforced concrete beams or slabs.*

Grouting:

1. *Grouting of cells, particularly those containing reinforcing steel.*
2. *Potential for incomplete grouting because of large or pairs of reinforcing bars in one cell or in bond beams.*
3. *Bond beams at required spacing and location.*
4. *Splice lengths for vertical and horizontal reinforcing.*
5. *Quality of construction joint at base of wall and vertical control joints.*

Wall and diaphragm connections:

1. *Wall and joints and separations for pounding or hard-spot effects.*
2. *Wall-reinforcing ties at wall intersections and corners.*
3. *Wall-to-diaphragm connections.*

1645A.4.4 *Where an element is unreinforced masonry, then the seismic capacities shall be determined in the manner consistent with the testing requirements specified in the Uniform Code for Building Conservation (UCBC).* ***[For OSHPD 1]*** *For hospital buildings, the use of unreinforced bearing wall masonry elements for seismic resistance is not allowed.*

1645A.4.5 *For masonry buildings with wood diaphragms, the requirements for Flexible Diaphragm-Rigid Wall Buildings of Uniform Code for Building Conservation, Appendix Chapter 5, shall apply.* ***[OSHPD 1]*** *For masonry hospital buildings with wood diaphragms the requirements of these regulations for new construction shall apply. The procedures for Flexible Diaphragm-Rigid Wall Buildings of the UCBC. Appendix Chapter 5 may be used, subject to the limitations of these regulations for new construction.*

1645A.4.6 Inspections Required. *Unless inspection reports from the original construction are available and acceptable, then appropriate destructive testing and inspections shall be performed, including core testing and removing masonry. For each wall that is part of the lateral-resisting system, at least one of each of the following tests shall be done:*

1. Core test to determine the strength of the masonry, the bond between the grout and the masonry units, and the placement and size of reinforcing steel in the walls.

2. At sections of the construction joints where masonry adjoins concrete at slab, concrete framing or foundations, determine the value of shear transfer.

1645A.5 Structural Steel.

1645A.5.1 Welded steel moment frame elements. *The SAC references in this section are to the SAC Interim Guidelines for the Evaluation, Repair, Modification, and Design of Welded Steel Moment Frame Structures, FEMA 267, August, 1995.*

1645A.5.1.1 *Any frame element in conformance with the requirements of Chapter 7 of the FEMA 267 requirements for new construction or which has had its connections repaired and modified in accordance with the recommendations of Chapter 6 may be classified as ductile and the β value taken as 1.0.*

1645A.5.1.2 *For any frame element in essential conformance with the requirements of 1976 UBC Section 2722 for Seismic Zones 3 and 4 or later editions of the UBC, where the structure:*

1. Has not experienced potentially damaging ground motions in an earthquake that by the recommendations of Chapter 4 of SAC Guideline FEMA 267 require inspection may be classified as limited-ductile and the β value taken as 1.5; or

2. Has been repaired and evaluated in conformance with the recommendations of Chapters 4 and 6 of FEMA 267 may be classified as limited-ductile and the β value taken as 1.5 or greater; or

3. Has been repaired in conformance with the requirements of Chapter 6 of FEMA 267 requirements for the repair may be classified as limited-ductile and the β value taken as 2.0 or greater; or

4. Has been inspected in accordance with the requirements of Chapters 3 and 4 of FEMA 267,

4.1 Connections that have been inspected but not repaired or modified may be classified as limited-ductile and the β value taken as 1.5 + .5d_i, where d_i is the damage index for the inspected connections.

4.2 Connections that have not been inspected may be classified as limited-ductile and the β value taken as 1.5 + .5DA, where DA is the average damage index for the inspected connections.

4.3 Connections that have been modified in accordance with the recommendations for Chapters 4 and 6 of FEMA 267 may be classified as ductile and the β value taken as 1.0.

4.4 Connections that have been repaired in accordance with the recommendations of Chapters 4 and 6 of FEMA 267 may be classified as limited-ductile and the β value taken as 1.5; or

5. Has not been inspected in accordance with the requirements of Chapters 3 and 4 of FEMA 267, the connections of the structure may be classified as limited ductile and the β value taken as 3.0 or higher.

1645A.5.1.3 *Any bolted frame element in conformance with the requirements of the 1997 UBC for bolted connections may be classified as ductile and the β value taken as 1.0. Where the frame element at least meets the requirements of 1976 UBC but not the 1997 requirements, then the element may be classified as limited-ductile and the β value taken as 1.5 or higher.*

1645A.5.1.4 *Any structural element having moment capacity but not qualifying as ductile under any UBC code provisions since 1976 may be classified as limited-ductile and the β value taken as 3.0 or higher.*

1645A.5.1.5 *Any truss girder or knee brace frame element may be classified as limited-ductile and the β value taken as 2.0 or higher.*

1645A.5.1.6 *Elements of frames with lateral girder buckling and/or noncompact column sections may be classified as limited-ductile and the β value taken as 2.0 or higher.*

1645A.5.2 Braced steel frame elements.

1645A.5.2.1 *Any braced frame element in conformance with the requirements of 1997 UBC for braced frames may be classified as ductile and the β value taken as 1.0.*

1645A.5.2.2 *Any braced frame element in conformance with the requirements of 1997 UBC, except that the b/t ratio exceeds the 1997 requirements for braced frames may be classified as limited-ductile and the β value taken as 1.5 for a special and 2.5 for ordinary braced frames.*

1645A.5.2.3 *Any braced frame element with tension-only bracing, with rods or angles, may be classified as limited-ductile and the β value taken as 2.0 or greater.*

1645A.5.2.4 *Any braced frame element with tension-only bracing, with rods or angles, may be classified as limited-ductile and the β value taken as 3.0 or greater.*

1645A.6 Wood and Other Sheathing Materials.

1645A.6.1 *Wood elements and other sheathing materials that essentially comply with the 1976 UBC Chapter 25, Wood, and Chapter 47, Installation of Wall and Ceiling Coverings, or the equivalent sections of later editions may be classified as ductile and assigned a β value of 1 as given in Table 16A-R-2.*

EXCEPTION: *Let-in bracing, plaster (stucco), gypsum wallboard and particle board sheathing shall be classified as limited-ductile or nonductile and assigned a β value given in Table 16A-R-2.*

1645A.6.2 *Any element not meeting the requirements of Section 1645A.6.1 shall be classified as nonductile, with a corresponding β value equal to or greater than that given in Table 16A-R-2, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:*

1. Anchoring attachment of tile or other heavy roofing elements, and chimneys.
2. In-plane and out-of-plane bracing of roof framing and trusses.
3. Wall-to-diaphragm connection for framing perpendicular to wall.
3.1 Indirect shear path.
4. Wall-to-diaphragm connection for framing parallel to wall.
5. Shear transfer connection from shear panels or walls to framing and/or collector elements at top and bottom of shear walls.
6. Wall hold-down details between floors and a positive load path to foundation at base of wall.
7. Attachment of sheathing and stucco to transfer shear from wall to foundation.
8. Sill bolts to transfer from wall framing to foundation.
9. Scabs and blocking and connections needed to transfer shear through floor framing.

1645BA.7 [OSHPD 1: Nonstructural Components and Systems Critical to Patient Care]

1645A.7.1 *The requirements of Section 1643A.9 applies to the following systems for the indicated systems for the indicated nonstructural performance levels NPC-1 through NPC-5, as defined in Chapter 6, Part 1, Title 24, Building Standards Administrative Code:*

EXCEPTION: *All exterior nonbearing, nonshear wall panels or elements that are not considered as part of the structural system shall be assessed using the requirements of Section 1646A.2.4.2, not Section 1645A.7.*

1645A.7.1.1 *For the NPC-1 performance level the requirements of Section 1643A.9 for nonstructural elements and systems do not apply.*

1645A.7.1.2 *For the NPC-2 performance level the requirements of Section 1643A.9 must be met by the following sytems:*

1. Communication Systems;
2. Emergency power systems;
3. Bulk medical gas systems;
4. Fire alarm systems; and
5. Emergency lighting equipment and signs in the means of egress.

1645A.7.1.3 *For the NPC-3 performance level the requirements of Section 1643A.9 must be met by the following systems in critical care areas, clinical laboratory, service spaces, pharmaceutical service spaces, and central and sterile supply areas:*

1. Those required by Section 1645A.7.1.2;

2. Nonstructural components, as listed in the 1995 California Building Code, Title 24, Part 2, Table 16A-O; and

3. Equipment listed in the 1995 California Building Code, Part 2, Title 24, California Code of Regulations, Table 16A-O "Equipment" including equipment in the physical plant that services these areas.

EXCEPTIONS: *1. For Section 1645A.7.1.3, seismic restraints need not be provided for cable trays, conduit and HVAC ducting. Seismic restraints may be omitted from piping systems, provided that an approved method of preventing release of the contents of the piping system in the event of a break is provided.*

2. For Section 1645A.7.1.3, only elevator(s) selected to provide patient, surgical, obstetrical and ground floors during the interruption of normal power need meet the structural requirements of Part 2, Title 24.

4. Fire sprinkler systems must comply with the bracing and anchorage requirements of NFPA-13, 1994 edition, or subsequent applicable standards.

EXCEPTION: *Acute care hospital facilities in both a rural area as defined in Section 70059.1, Division 5 of Title 22 and Seismic Zone 3 shall comply with the bracing and anchorage requirements of NFPA 13, 1994 edition or subsequent applicable standards as specified in Article 11, Chapter 6, Part 1, Title 24, Building Standards Administrative Code.*

1645A.7.1.4 *For the NPC-4 performance level the requirements of Section 1643A.9 must be met by the following systems:*

1. Those required by Section 1645A.7.1.3; and

2. All architectural, mechanical and electrical systems, components and equipment and hospital equipment bracing and anchorages.

1645A.7.1.5 *For the NPC-5 performance level, the requirements of Section 1643A.9 must be met by the following systems:*

1. Those required by Section 1645A.7.1.4;

2. On-site supplies of water and holding tanks for wastewater, sufficient for 72 hours of emergency operations, that are integrated into the building plumbing system, including any alternative hook-ups to allow the use of transportable water and sanitary waste water disposal; and

3. On-site emergency system as defined within Part 3, Title 24; this includes task lighting, selected outlets and ventilation systems, radiological service, and on-site fuel supply for 72 hours of acute care operation.

1645A.7.2 *The β values to be used in Section 1644A.13.1 and Formula 44A-11 for the connection and bracing of nonstructural elements, equipment and systems shall be determined as follows:*

1645A.7.2.1 Ductile or Code Complying: *Any element constructed under a permit issued by OSHPD may be classified as ductile and the β value taken as 1.0.*

1645A.7.2.2 Nonductile: *Any element whose construction was completed before 1973 shall be classified as nonductile and β taken as 4.0, except where Section 1645A.2 or 1646A.2.4.2 allow use of another value. The Section 1645A.2.2 analysis shall consider at a minimum:*

1. The anchorage of the element to the structural system.

2. The yielding and post yielding, buckling, and/or failure behavior of the connection and/or bracing system.
3. The attachment of supported equipment to the brace and bracing system and the ability to reliably develop yielding in the connection and/or brace.
4. Stability of the bracing system under both in-plane and out-of-plane displacements of the supported equipment.

1645A.7.2.3 Limited-Ductile: *Systems and elements that do not comply with Section 1645A.7.2.1 or 1645A.7.2.2 shall be classified as limited-ductile, with corresponding β value equal to or greater than 2.5 for all modes of failure, except where Section 1645A.2 allows use of another value. The Section 1645A.2.2 analysis shall consider at a minimum the items 1 through 4 listed in Section 1645A.7.2.2.*

EXCEPTION: *All drilled mechanical anchors subject to tension loads shall be classified as nonductile, except that they may be classified as ductile where tension testing, consistent with OSHPD, DSA or comparable procedures, has been completed for the anchors and the results of testing are evaluated as acceptable.*

SECTION 1646A-DETAILED SYSTEMS DESIGN REQUIREMENTS

1646A.1 General. *All structural framing systems shall comply with the requirements of Section 1643A.0. The individual elements shall have the usable strength capacity ϕC_n or the allowable capacity C_w to resist the prescribed seismic load combinations. In addition, such framing systems and elements shall comply with the detailed design requirements contained in Section 1646A.*

1646A.1.1 *All building components in Seismic Zones 3 and 4 shall be designed to resist the effects of the seismic forces prescribed herein and the effects of gravity loadings from dead, floor live and snow loads.*

1646A.1.2 *Consideration shall be given at each story level to the effects of uplift, reversed moment and/or sliding, caused by seismic loads, as prescribed in Sections 1646A.1.3 and 1646A.2.4.2.*

1646A.1.3 *The following provisions apply for all levels of the superstructure and its connection to the foundation structure:*

1646A.1.3.1 *Overturning moment tension resistance for elements and connections: If the tension action due to $\Omega_o E$ - 0.9D >0, then the usable tensile strength ϕC_n shall equal or exceed the greater of the tension due to $\Omega_o E$ - 0.9D or E/14 for semi-ductile and brittle elements; and E - 0.9D or E/14 for ductile elements.*

1646A.1.3.2 *Reversed Moment opposite to that caused by gravity loads in beams, slabs, and spandrels: If the flexural action due to $\Omega_o E$ - 0.9D >0, then the usable flexural strength ϕC_n shall equal or exceed the greater of the moment due to $\Omega_o E$ - 0.9D or E/14 for semi-ductile and brittle elements; and E - 0.9D or E/14 for ductile elements.*

1646A.1.3.3 *Resistance to sliding or slip of horizontal joints and/or the in-plane joints between diaphragms and walls or frames shall be such that the usable horizontal shear strength* ϕC_n *equals or exceeds the shear on the joint due to* E.

1646A.1.3.4 *For the following conditions:*

1. Foundations at the soil-structure interface;
2. Horizontal construction joints in shear walls; or,
3. Diaphragm collectors, joints or connections of diaphragms to shear walls or frames.

If the strength capacity to resist overturning and/or sliding is exceeded by the application of a load combination of

$$\Omega_o E - 0.9D \qquad (46A\text{-}1)$$

then the deformations to be used in the investigation required by Section 1646A.2.4 shall be two times the displacement prescribed by Section 1646A.2.4.

1646A.1.4 *In Seismic Zones 3 and 4, provision shall be made for the effects of earthquake forces acting in a direction other than the principal axes in each of the following circumstances:*

1. The structure has plan irregularity Type E as given in Table 16A-M.
2. The structure has plan irregularity Type A as given in Table 16A-M for both major axes.
3. A column of a structure forms part of two or more intersecting lateral-force-resisting systems.

EXCEPTION: *If the axial load in the column due to seismic forces acting in either direction is less than 20 percent of the column allowable axial load.*

The requirement that orthogonal effects be considered may be satisfied by designing such elements for 100 percent of the prescribed seismic forces in one direction plus 30 percent of the prescribed forces in the perpendicular direction. The combination requiring the greater component strength shall be used for design. Alternatively, the effects of th two orthogonal directions may be combined on a square root of the sum of the squares (SRSS) basis. When the SRSS method of combining directional effects is used, each term computed shall be assigned the sign that will result in the most conservative result.

1646A.2 Structural Framing Systems.

1646A.2.1 General. *Four types of general building framing systems defined in Section 1629A.6 are recognized in these provisions and shown in Table 16A-N, Each type of is subdivided by the types of vertical elements used to resist lateral seismic forces. Special framing requirements are given in this section and in Chapters 19A through 23A.*

1646A.2.2 Detailing for combinations of systems. *For components common to different structural systems, the more restrictive detailing requirements shall be used.*

1646A.2.3 Connections. *Connections that resist seismic forces shall be designed and detailed on the drawings.*

1646A.2.4 Deformation compatibility. *All vertical load bearing elements not included as a part of the lateral force resisting system shall be investigated and shown to be adequate for vertical load carrying capacity when displaced (0.7)R times the displacements resulting from the required design lateral forces given in Section 1644A.4. A representation of cracked section stiffness properties for reinforced concrete and masonry elements shall be used in the calculation of the displacements. The displacements shall include diaphragm deformation.*

For designs using working stress methods, this capacity may be determined using an allowable stress increase of 1.7 or acceptable published factors for a given material or element. The effects of adjoining rigid and exterior elements shall be considered as follows.

1646A.2.4.1 Adjoining rigid elements. *Any framing elements, including those of the lateral -force-resisting system, may be enclosed by or adjoined by more rigid elements, which would tend to limit the frame from resisting lateral forces, where it can be shown that the action or failure of the more rigid elements will not impair the vertical and lateral-load-resisting ability of the frame. Where failure of the more rigid elements is indicated, then the life-safety consequences due to debris and other falling hazards shall be investigated and mitigated where appropriate.*

1646A.2.4.2 Exterior elements. *Exterior nonbearing, non- shear wall panels or elements that are attached to or enclose the exterior of the structure shall be designed to resist the forces per Formulas (44A–14) or (44A-15) and shall accommodate movements of the structure resulting from lateral forces or temperature changes. In order to qualify for the "code-complying or ductile" classification such elements shall be supported by means of cast–in–place concrete or by mechanical connections and fasteners in accordance with the following provisions:*

1. *Connections and panel joints shall allow for a relative movement between stories of not less than two times story drift caused by wind or the story drift corresponding to the (0.7) R factored displacements given in Section 1646A.2.4, (0.015 h), or 0.5 inch (13 mm), whichever is greater.*

2. *Connections to permit movement in the plane of the panel for story drift shall be sliding connections using slotted or oversize holes, connections which permit movement by bending of steel, or other connections providing equivalent sliding and ductility capacity.*

3. *Bodies of connections shall have sufficient ductility and rotation capacity so as to preclude fracture of the concrete or brittle failures at or near welds.*

4. *The body of the connection shall be designed for one and one–third times the force determined by Formula (44A–14) or (44A-15) where R_p = 3.0 and a_p = 1.0.*

5. *All fasteners in the connecting system such as bolts, inserts, welds and dowels shall be designed for four times the force determined by Formula (44A-14) or (44A–15) where R_p = 3.0 and a_p = 1.0.*

6. *Fasteners embedded in concrete shall be attached to, or hooked around, reinforcing steel or otherwise terminated so as to effectively transfer forces to the reinforcing steel.*

1646A.2.5 Ties and continuity. *All parts of a structure shall be interconnected and the connections shall be capable of transmitting the seismic force induced by the parts being connected. As a minimum, any smaller portion of the building shall be tied to the remainder of the building with elements having at least a strength to resist 0.5HC_aI times the weight of the smaller portion.*

A positive connection for resisting a horizontal force acting parallel to the member shall be provided for each beam, girder or truss. This force shall not be less than 0.5HC_aI times the dead plus live load.

1646A.2.6 Collector elements. *Collector elements shall be provided that are capable of transferring the seismic forces originating in other portions of the building to the element providing the resistance to those forces. These elements shall be classified as "ductile," "limited-ductile," or "nonductile" and assigned the corresponding β factor for the seismic load. Unless an element can qualify for a β value given in Section 1645A, β shall be 1.00 for code-complying or ductile elements, and 4.00 for nonductile elements.*

1646A.2.7 Concrete frames. *In order to qualify for the "code-complying or ductile" classification and use of an R greater than 5.5, concrete frames that are part of the lateral–force–resisting system shall conform to the requirements of Division VI for special moment-resisting frames in seismic Zones 3 and 4.*

1646A.2.8 Anchorage of concrete or masonry walls. *Concrete or masonry walls shall be anchored to all floors and roofs that provide lateral support for the wall. The anchorage shall provide a positive direct connection between the wall and floor or roof construction capable of resisting the horizontal forces specified in Section 1611A or 1644A.13.1. Requirements for developing anchorage forces in diaphragms are given in Section 1646A.2.9. Diaphragm deformation shall be considered in the design of the supported walls.*

1646A.2.9 Diaphragms.

1646A.2.9.1 *The deflection in the plane of the diaphragm shall not exceed the permissible deflection of the attached elements. Permissible deflection shall be that deflection which will permit the attached element to maintain its structural integrity under the individual loading and continue to support the prescribed loads. For the purpose of this evaluation the deflection of the diaphragm shall be (0.7)R_w times the deflection Δ_s due to F_{px} with $\beta = 1.00$ in Formula (46A-2).*

1646A.2.9.2 *Floor and roof diaphragms shall be designed to resist the forces determined in accordance with the following formula:*

$$F_{px} = \beta \frac{F_t + \sum_{i=x}^{n} F_i}{\sum_{i=1}^{n} w_i} w_{px} \qquad (46A\text{-}2)$$

The force F_{px} determined from Formula (46A-2) need not exceed 1.0 β H C_a I w_{px} but shall not be less than 0.5 β H C_a I w_{px}. The β value to be used in the capacity analysis is the factor appropriate to the element and condition of loading. The actions on an element due to the force F_{px} are the seismic load E. The value of β shall be 1.00 for code complying or essentially complying elements and 4.00 for non-ductile elements, unless the element qualifies for a lower value as given in Table 16A-R-1 or 16A -R-2.

1646A.2.9.3 *When the diaphragm is required to transfer lateral forces from the vertical-resisting elements above the diaphragm to other vertical-resisting elements below the diaphragm due to offset in the placement of the elements or to changes in stiffness in the vertical elements, these forces shall be added to those determined from Formula (46A-2).*

1646A.2.9.4 *Design forces for flexible diaphragms and their connections providing lateral supports for walls or frames of masonry or concrete shall be calculated using an R not to exceed 4.*

1646A.2.9.5 *Diaphragms supporting concrete masonry walls shall have continuous ties or struts between diaphragm chords to distribute the anchorage forces specified in Section 1644A.13.1. Added chords may be used to form subdiaphragms to transmit the anchorage forces to main cross ties.*

1646A.2.9.6 *Where wood diaphragms are used to laterally support concrete or masonry walls, the anchorage shall conform to Section 1644A.13.1. Anchorage shall not be accomplished by use of toenails or nails subject to withdrawal, nor shall wood ledgers or framing be used in cross-grain bending or cross-grain tension, and the continuous ties required by Section 1646A.2.9.5 shall be in addition to the diaphragm sheathing.*

> ***EXCEPTION:*** *The prohibited details may be used if an appropriate β factor is assigned to allow for nonductile behavior.*

1646A.2.10 Framing below the base. *Elements of the lateral-force-resisting system and all framing elements between the base and the foundation are subject to the same provisions as required for the superstructure.*

1646A.2.11 Building separations. *When the gap separating the building from adjacent structures is less than 0.7R times the displacement due to seismic forces of the building, Δ_s then the effects of pounding shall be investigated and the structure modified so that pounding or interaction does not pose a life-safety threat to the building.*

EXCEPTION: *Smaller separations may be permitted when justified by rational analyses based on maximum expected ground motions. Under this exception, as a minimum, building separations shall not be less than R/5.5 times the displacements due to specified seismic forces.*

SECTION 1647A - NONBUILDING STRUCTURES

1647A.1 General*. Nonbuilding existing structures include all self–supporting structures other than buildings which carry gravity loads and resist the effects of earthquake. Nonbuilding existing structures shall be designed to resist the minimum lateral forces specified in this division. Design shall conform to the applicable provisions of Section 1634A for new structures except as modified by the provisions contained in this division.*

SECTION 1648A-METHOD B

1648.1 *The existing or retrofitted structure shall be demonstrated to have the capability to sustain the deformation response due to the specified earthquake ground motions. The engineer shall provide an evaluation of the response of the existing structure in its current configuration and condition to the ground motions specified. If the building's seismic performance is evaluated as satisfactory and the peer reviewer(s) [For OSHPD 1: and the enforcement agent] concurs, then no further engineering work is required. When the evaluation indicates the building does not meet the objective of safety goals of this division [For OSHPD 1: and the applicable structural seismic performance (SPC) and nonstructural seismic performance (NPC) requirements,] then a retrofit and/or repair design shall be prepared that yields a structure that meets the life-safety [For OSHPD 1: and operational] performance objectives of Section 1640A this division and reflects the appropriate consideration of existing conditions. Any approach to analysis and design may be used that yields a building of reliable stability in the prescribed design earthquake loads and conditions. The approach shall be rational, shall be consistent with the established principals of mechanics, and shall use the known performance characteristics of materials and assemblages under reversing loads typical of severe earthquake ground motions.*

EXCEPTION: *Further consideration of the structure's seismic performance can be waived by the Enforcement Agent if both the engineer-of-record and peer reviewer(s) [OSHPD 1: and/or Enforcement Agent] conclude that the structural system can be expected to perform at least as well as required by the provisions of this division without completing an analysis of the structure's conformance to these requirements. A detailed report shall be submitted to the responsible Enforcement Agent that presents the reasons and basis for this conclusion. This report shall be prepared by the engineer of record. The peer reviewer(s) [OSHPD 1: and/or Enforcement Agent] shall concur in this conclusion and affirm to it in writing.*

1648A.2 *The approach, models, analysis procedures, assumptions on material and system behavior, and conclusions shall be peer reviewed in accordance with the requirements of Section 1649A and accepted by the peer reviewer(s) [OSHPD 1: and Enforcement Agent].*

EXCEPTIONS*: 1) The enforcement agency may perform the work of peer review when qualified staff is available within the jurisdiction.*
2) The enforcement agency may modify or waive the requirements for peer review when appropriate.

1648A.2.1…[For DSA/SS]
1648A.2.2…[For DSA/SS]

1648A.2.3 *The approach used in the development of the design shall be acceptable to the peer reviewer. Approaches that are specifically tailored to the type of building, construction materials and specific building characteristics may be used, if they are acceptable to the independent peer reviewer. Section 1648A.3 provides several approaches that may be considered. The following conditions apply to whatever approach is selected.*

1648A.2.3.1 *If load (e.g., R_w,β) factors, capacity reduction factors (e.g., φ), or measures of inelastic deformation capability (e.g., IDR_L, μ_L, ε_L, rotation, θ_L) are used, the basis for their use and the specific values assigned shall be assessed and supported in a consistent manner.*

1648A.2.3.2 *Where dynamic time history analysis is used, at least three distinct representative records with simultaneous loadings in different directions, as appropriate, shall be used in the analysis. The maximum response parameter of interest shall be used for design.*

1648A.2.3.3 *When an elastic analysis approach is adopted, the stiffness characteristics for the elements of the elastic model should be representative of the inelastic behavior at the maximum response for the strength degrading materials and the nominal strength deformation for nondegrading materials. The following items are given for consideration:*

1. *For reinforced concrete frame elements and reinforced concrete and masonry shear wall elements, this stiffness may be taken as one-half of that of the gross section or that of the cracked section. A more appropriate value may be used if justified by analysis.*
2. *Steel framing and bracing elements are to have their elastic section stiffness.*
3. *Steel-framing elements encased in reinforced concrete are to have the composite section stiffness which may be taken as 1.3 times the concrete gross-section stiffness, and beam-column joints may be assumed to be rigid.*
4. *Framing elements shall have model lengths equal to the clear span length, or have a suitable rigid element representation of the joint configuration.*
5. *If framing element connections and/or supports are not fully rigid, then these shall be modeled as springs.*
6. *The representation of foundation flexibility shall be included when it results in more than a 25-percent reduction in the assumed full fixity of supported elements. This includes the effects of both rotational and horizontal deformations and sliding.*

1648A.2.3.4 *Reliable capacities shall be used for all elements, consistent with the fundamental behavior of the element and/or system under reversing loads at the design level of earthquake loads.*

1648A.2.3.5 *The value of the earthquake loading of an element need not exceed the force action induced in the element when the inelastic structure is displaced due to the* *prescribed ground motions, and the elements are assigned their probable strength values.*

1648A.2.3.6 *All structural elements that can affect life safety shall be shown to have acceptable behavior in the design loadings. For structural elements not considered as part of the lateral-load-resisting system, the requirements of Section 1644A.13 are sufficient to meet this requirement.*

1648A.2.4 *The ground motion characterization used for Method B shall be consistent with those required by Section 1643A.8.*

1648A.2.4.1 [For OSHPD 1] *The ground motion characterization used for Method B shall be based on ground shaking having a 10 percent probability of exceedance in 50 years for category SPC 2 at the essential life-safety performance level. For SPC 3 through SPC 5, the ground motion characterization used for Method B shall be based on ground shaking having a 10 percent probability of exceedance in 50 years at the immediate occupancy performance level and the maximum considered earthquake at the collapse prevention performance level.*

Ground shaking having a 10 percent probability of exceedance in 50 years need not exceed 2/3 of the maximum considered earthquake.

Ground shaking response spectra for use in Method B shall be determined in accordance with either the General Procedure of Section 1648A.2.4.2 or the Site-Specific Procedure of Section 1648A.2.4.3.

In the General Procedure, ground shaking hazard is determined from the response spectrum acceleration contour maps. Maps showing 5%-damped response spectrum ordinates for short-period (0.2 second) and long-period (1.0 second) response distributed by FEMA for use with the "NEHRP Guidelines for the Seismic Rehabilitation of Buildings" (FEMA 273) shall be used directly with the General Procedure of Section 1648A.2.4.2 for developing design response spectra for either or both the 10% probability of exceedance in 50 years and the maximum considered earthquake. In the Site-Specific Procedure, ground shaking hazard is determined using a specific study of the faults and seismic source zones that may affect the site, as well as evaluation of the regional and geologic conditions that affect the character of the site ground motion caused by events occurring on these faults and sources.

The General Procedure may be used for any building. The Site-Specific Procedure may also be used for any building and shall be required where any of the following apply:

1. *The building is category SPC-5;*
2. *The building site is located within 10 kilometers of an active fault;*
3. *The building is located on Type E soils (as defined in Section 1648A.2.4.2) and the mapped maximum considered earthquake spectral response acceleration at short periods (S_S) exceeds 2.0g;*
4. *The building is located on Type F soils as defined in Section 1648A.2.4.2.*

EXCEPTION: *Where S_S determined in accordance with Section 1648A.2.4.2, < 0.20g. In these cases, a Type E soil profile may be assumed.*

5. A time history response analysis of the building is performed as part of the design.

1648A.2.4.2 [For OSHPD 1] General Procedure to Determine the Acceleration Response Spectra. *The general procedures of this section shall be used to determine the acceleration response spectra.*

Deterministic estimates of earthquake hazard, in which an acceleration response spectrum is obtained for a specific magnitude earthquake occurring on a defined fault, shall be made using the Site-Specific Procedures of Section 1648A2.4.3.

The mapped short-period response acceleration parameter, S_s, and mapped response acceleration parameter at a 1-second period, S_1, for 10 percent probability of exceedance in 50 years ground motion shall be obtained directly from the maps distributed by FEMA for use with the "NEHRP Guidelines for the Seismic Rehabilitation of Buildings" (FEMA 273). The mapped short-period response acceleration parameter, S_s, and mapped response acceleration parameter at a 1-second period, S_1, for the maximum considered earthquake shall also be obtained directly from the maps.

Parameters S_s and S_1 shall be obtained by interpolating between the values shown on the response acceleration contour lines on either side of the site, on the appropriate map, or by using the value shown on the map for the higher contour adjacent to the site.

The mapped short-period response acceleration parameter, S_s, and mapped response acceleration parameter at a 1-second period, S_1, for 10 percent probability of exceedance in 50 years ground shaking hazards shall be taken as the smaller of the following:

1. The values of the parameters S_s and S_1, respectively, determined for 10 percent probability of exceedance in 50 years ground motion.

2. Two-thirds of the values of the parameters S_s and S_1, respectively, determined from the maximum considered earthquake ground motion map.

The design short-period spectral response acceleration parameter, S_{xs}, and the design spectral response acceleration parameter at 1 second, S_{x1}, shall be obtained, respectively, from Equations (48A-1) and (48A-2) as follows:

$$S_{xs}=F_aS_s \qquad (48A\text{-}1)$$

$$S_{x1}=F_vS_1 \qquad (48A\text{-}2)$$

where F_a and F_v are site coefficients determined respectively from Tables 16A-R-3 and 16A-R-4, based on the site class and the values of the response acceleration parameters S_s and S_1.

Site classes shall be defined as follows:

Class A: *Hard rock with a measured shear wave velocity, $\bar{v}$>5,000 ft/sec(1524m/s).*

Class B: *Rock with 2,500 ft/sec (762 m/s) < $\bar{v}$ < 5,000 ft/sec (1524 m/s).*

Class C: *Very dense soil and soft rock with 1,200 ft/sec (366m/s) < $\bar{v}_s \leq$ 2,500 ft/sec (762 m/s) or with either standard blow count $\bar{N}$ > 50 or undrained shear strength $\bar{s}_u$ > 2,000 pounds per square feet (psf) (96kN/m^2).*
Class D: *Stiff soil with 600 ft/sec (48kN/m^2) < $\bar{v}_s \leq$ 1,200 ft/sec (366 m/s) or with 15 < $\bar{N} \leq$ 50 or 1,000 psf (48 kN/m^2) $\leq \bar{s}_u$ < 2,000 psf (96 kN/m^2).*
Class E: *Any profile with more than 10 feet (3048 mm) of soft clay defined as soil with plasticity index PI>20, or water content w>40 percent, and $\bar{s}_u$ < 500 psf (24kN/m^2) or a soil profile with $\bar{v}_s$ < 600 ft/sec (183 m/s). If insufficient data are available to classify a soil profile as Type A through D, a Type E profile shall be assumed.*
Class F: *Soils requiring site-specific evaluations:*
1. Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils.
2. Peats and/or highly organic clays (H >10 feet (3048 mm) of peat and/or highly organic clay, where H=thickness of soil).
3. Very high plasticity clays (H > 25 feet (7620 mm) with PI > 75 percent).
4. Very thick soft/medium stiff clays (H > 120 feet) [36 576 mm].
The parameters $\bar{v}s$, $\bar{N}$ and $\bar{s}u$ are, respectively, the average values of the shear wave velocity, Standard Penetration Test (SPT) blow count, and undrained shear strength of the upper 100 feet (30 480 mm) of soils at the site. These values shall be calculated from Equation (48A-3):

$$\bar{v}_s, \bar{N}, \bar{s}_u = \frac{\sum_{i=1}^{n} d_i}{\sum_{i=1}^{n} \frac{d_i}{v_{si}}, \frac{d_i}{N_i}, \frac{d_i}{s_{ui}}} \qquad \text{(48A-3)}$$

WHERE:
Ni = SPT blow count in soil layer "i."
n = Number of layers of similar soil materials for which data is available.
di = Depth of layer "i."
sui = Undrained shear strength in layer "i."
vsi = Shear wave velocity of the soil in layer "i."

and

Where reliable v_s data are available for the site, such data shall be used to classify the site. If such data are not available, N data shall be used for cohesionless soil sites (sands, gravels), and s_u data for cohesive soil sites (clays). For rock in profile classes B and C, classification may be based either on measured or estimated values of v_s. Classification of a site as Class A rock shall be based on measurements of v_s either for material at the site itself, or for similar rock materials in the vicinity; otherwise, Class B rock shall be assumed. Class A or B profiles shall not be assumed to be present if there is more than 10 feet (3048 mm) of soil between the rock surface and the base of the building.

A general, horizontal response spectrum shall be constructed by plotting the following two functions in the spectral acceleration vs. structural period domain, as shown in

Figure 16A-R-1. Where a vertical response spectrum is required, it may be constructed taking two-thirds of the spectral ordinates, at each period, obtained for the horizontal response spectrum.

$$S_a = (S_{xs} / B_s)(0.4 + 3T / T_o) \; for \; 0 < T \leq 0.2T_o \qquad (48A\text{-}5)$$

$$S_a = (S_{x1} / (B_1 T)), \; for \; T > T_o \qquad (48A\text{-}6)$$

where T_o is given by the equation

$$T_o = (S_{x1} B_s) / (S_{xs} B_1) \qquad (48A\text{-}7)$$

where B_s and B_1 are taken from Table 16A-R-5.

A 5-percent damped response spectrum shall be used for the design of buildings and structural systems, with the following exceptions:

1. For structures without exterior cladding, an effective viscous damping ratio, β, of 2 percent shall be assumed.

2. For structures with wood diaphragms and a large number of interior partitions and cross walls that interconnect the diaphragm levels, an effective viscous damping ratio, β, of 10 percent may be assumed.

3. For structures rehabilitated using seismic isolation technology or enhanced energy dissipation technology, the equivalent effective viscous damping ratio, β, shall be determined in accordance with Section 1629A.10.2.

1648A.2.4.3 [For OSHPD 1] Site-specific procedure to determine the acceleration response spectra. *Where site-specific ground shaking characterization is used as the basis of the design, the characterization shall be developed in accordance with this section.*

Development of site-specific response spectra shall be based on the geologic, seismologic and soil characteristics associated with the specific site. Response spectra shall be developed for an equivalent viscous damping ratio of 5 percent. Additional spectra may be developed for other damping ratios appropriate to the indicated structural behavior, as discussed in Section 1648A.2.4.2.

When the 5-percent damped site-specific spectrum has spectral amplitudes in the period range of the greatest significance to the structural response that are less than 70 percent of the spectral amplitudes of the General Response Spectrum, an independent peer review of the spectrum shall be made by an individual with expertise in the evaluation of ground motion in accordance with Section 1649A.

The maximum considered earthquake ground motion shall be taken as far as that motion represented by an acceleration response spectrum having a 2 percent probability of exceedance within a 50-year period. The maximum considered earthquake spectral response acceleration at any period shall be taken from the 2 percent probability of exceedance within a 50 year period spectrum as limited by the following:

Where the spectral response ordinates at 0.2 second or 1 second for a 5 percent damped spectrum having a 2 percent probability of exceedance within a 50-year period exceed the corresponding ordinates of the deterministic limit, the maximum considered earthquake ground motion spectrum shall be taken as the lesser of the probabilistic maximum considered earthquake ground motion or the deterministic maximum considered earthquake ground motion spectrum. The deterministic limit for the maximum considered earthquake ground motion response spectrum shall be calculated as 150 percent of the median spectral response accelerations at all periods resulting from a characteristic earthquake on any known active fault within the region and shall comply with the response spectrum determined in accordance with Figure 16A-R-2, where F_a and F_v are determined in accordance with Section 1648A.2.4.2, with the value of the mapped short period spectral response acceleration, S_s taken as 1.5 g , and the value of the mapped spectral response acceleration at 1 second S_1, taken as 0.6g.

When a site-specific response spectrum has been developed and other sections of these regulations require values for the spectral response parameters, S_{xs}, S_{x1}, or T_o, they shall be obtained in accordance with this section. The value of the design spectral response acceleration at short S_{xs}, shall be taken as the response acceleration obtained from the site-specific spectrum at a period of 0.2 second, except that it shall be taken as not less than 90 percent of the peak response acceleration at any period. In order to obtain a value for the design spectral response acceleration parameter S_{x1}, a curve of the form $S_a=S_{x1}/T$ shall be graphically overlaid on the site-specific spectrum such that at any period, the value of S_a obtained from the curve is not less than 90 percent of that which would be obtained directly from the spectrum. The value of T_o shall be determined in accordance with the Equation (48A-8). Alternatively, the values obtained in accordance with Section 1648A.2.4.2 may be used for all of these parameters.

$$T_o = S_{x1}/S_{xs} \qquad (48A\text{-}8)$$

Time-history analysis shall be performed with no fewer than three data sets (two horizontal components or, if vertical motion is to be considered, two horizontal components and one vertical component) of appropriate ground motion time histories that shall be selected and scaled from no fewer than three recorded events. Appropriate time histories shall have magnitude, fault distances and source mechanisms that are consistent with those that control the design earthquake ground motion. Where three appropriate recorded ground-motion time-history data sets are not available, appropriate simulated time-history data sets may be used to make up the total number required. For each data set, the square root of the sum of the squares (SRSS) of the 5-percent damped site-specific spectrum of the scaled horizontal components shall be constructed. The data sets shall be scaled such that the average value of the SRSS spectra does not fall below 1.4 times the 5-percent damped spectrum for the design earthquake for periods between 0.2T second and 1.5T seconds (where T is the fundamental period of the building).

Where three time-history data sets are used in the analysis of the structure, the maximum value of each response parameter (e.g., force in a member, displacement at a specific level) shall be used to determine design acceptability. Where seven or more *time-history data sets are employed, the average value of each response parameter shall be used to determine design acceptability.*

1648A.2.5 *Whatever evaluation or analysis method is used in meeting the requirements of Section 1648A, the designer shall, unless the exception of Section 1648A.1 applies, at a minimum.*

1648A.2.5.1 *Identify all elements and systems (both vertical and horizontal) that are subject to the response loads and deformations due to the specified maximum expected earthquake ground shaking. Elements include beams, columns, joints, connections, walls, diaphragms, construction joints, precast element joints, exterior panel connections, bracing, diaphragms, collectors, diaphragm-to-wall or frame connection and foundations.*

1648A.2.5.2 *Identify the vertical elements (e.g., walls, frames, braced frames, in-filled frames, moment frames, etc.) that will participate in the lateral-load-resisting system.*

1648A.2.5.3 *Identify the horizontal or nearly horizontal elements that form the diaphragm systems that interconnect the vertical elements, along with the chords, drags or collector elements, and connections to the vertical systems, and the internal connections within the diaphragm (precast planks, metal decking, bracing systems, pour-strips for prestressed slabs, etc.).*

1648A.2.5.4 *Identify the foundation system supporting the lateral-load-resisting system, including all connections and the means of resisting the actions of overturning moment and sliding.*

1648A.2.5.5 *Assign the expected strength level to all elements for all of their possible modes of yielding or failure. For reinforced concrete, use nominal capacity. For structural steel, use either 1.7 times allowable stress capacity or the nominal capacity from LRFD. For all other materials, use either 1.7 times allowable stress capacity or estimated strength from tests and/or existing research results.*

1648A.2.5.6 *Assign the effective elastic stiffness for all elements for each type and directional sense of action (flexural, shear, torsion, axial) that the element shall resist. The effective stiffness should be the best estimate of the secant stiffness at the development of the element strength representing the onset of the constant yield threshold.*

1648A.2.5.7 *Assign the element deformation behavior beyond the development of the strength or constant yield threshold for each mode of failure or yielding. Identify elements having a sudden brittle or buckling mode of failure. The effects of reversed cycles of loading should be considered to evaluate the degree of strength degradation and/or the pinching of the shape of the hysterisis loop. The deformation behavior may be in the form of load-deformation curves, allowable inelastic demand ratio (IDR_L) values, or allowable ductility demand (μ_L) values, or maximum allowable strain values ε_L or allowable rotation values θ_L. The classification of the elements as "ductile," "limited-ductile," or "nonductile" may be a part of the element deformation behavior description.*

1648A.2.6 *Prior to implementation, the procedures, methods, material assumptions and acceptance/rejection criteria proposed by the engineer will be peer reviewed as provided in Section 1649A.*

1648A.2.7 *The conclusions and design decisions shall be reviewed and accepted by the peer reviewer(s).*

1648A.3 [Not adopted by DSA/SS] *Any method of analysis meeting the requirements of Sections 1648A.2 and 1648.3 may be used, subject to acceptance by the peer reviewer(s). Among those that can be used are the following types of analysis and assessment provisions, if the specific characteristics of the structure warrant their use:*

1. *Equivalent stiffness (or substitute structure) methods.*
2. *Inelastic demand ratio methods.*
3. *Pushover or capacity spectrum methods.*
4. *Inelastic time-history methods.*

SECTION 1649A- PEER REVIEW REQUIREMENTS

1649A.1 General. *Independent peer review is an objective technical review by knowledgeable reviewer(s) experienced in the structural design, analysis and performance issues involved. The reviewer(s) shall examine the available information on the condition of the building, the basic engineering concepts employed and recommendations for action.*

1649A.2. [Not adopted by DSA/SS] Timing of Independent Review. *The independent reviewer(s) shall be selected prior to initiation of substantial portions of the design and/or analysis work that is to be reviewed, and review shall start as soon as practical after Method B is adopted and sufficient information defining the project is available.*

1649A.3. Qualifications and Terms of Employment. *The reviewer shall be independent from the design and construction team.*

1649A.3.1 *The reviewer(s) shall have no other involvement in the project before, during or after the review, except in a review capacity.*

1649A.3.2 *The reviewer shall be selected and paid by the owner and shall have technical expertise in repair of buildings similar to the one being reviewed, as determined by the responsible enforcement agent.*

1649A.3.3 *The reviewer (or in the case of review teams, the chair) shall be a California-licensed structural engineer who is familiar with the technical issues and regulations governing the work to be reviewed.*

1649A.3.4 *The reviewer shall serve through completion of the project and shall not be terminated except for failure to perform the duties specified herein. Such termination shall be in writing with copies to the enforcement agent, owner, and the engineer of* *record. When a reviewer is terminated or resigns, a qualified replacement shall be appointed within 10 working days.*

1649A.4. [Not adopted by DSA/SS] Scope of Review. *Review activities shall include, where appropriate, available construction documents, observations of the condition of the structure, all inspection and testing reports, including methods of sampling, analyses prepared by the engineer of record and consultants, and the retrofit or repair design. Review shall include consideration of the proposed design approach, methods, materials and details.*

1649A.5. [Not adopted by DSA/SS] Reports. *The reviewer(s) shall prepare a written report to the owner and responsible enforcement agent that covers all aspects of the review performed, including conclusions reached by the reviewer. Reports shall be issued after the schematic phrase, during design development, and at the completion of construction documents, but prior to their issuance for permit. Such reports should include, at a minimum, statements of the following:*

1. *Scope of engineering design peer review with limitations defined.*
2. *The status of project documents at each review stage.*
3. *Ability of selected materials and framing systems to meet performance criteria with given loads and configuration.*
4. *Degree of structural system redundancy and the deformation compatibility among structural and nonstructural elements.*
5. *Basic constructibility of the retrofit or repair system.*
6. *Other recommendations that would be appropriate to the specific project.*
7. *Presentation of the conclusions of reviewer identifying any areas that need further review, investigation and/or clarification.*
8. *Recommendations.*

1649A.6. [Not adopted by DSA/SS] Responses and Corrective Actions. *The engineer of record shall review the report from the reviewer(s) and shall develop corrective actions and other responses as appropriate. Changes observed during the construction that affect the seismic-resisting system shall be reported to the reviewer in writing for review and recommendations. All reports, responses and corrective actions prepared pursuant to this section shall be submitted to the responsible enforcement agent and the owner along with other plans, specifications and calculations required. If the reviewer resigns or is terminated by the owner prior to completion of the project, then the reviewer shall submit copies of all reports, notes and correspondence to the responsible enforcement agent, the owner, and the engineer of record within 10 working days of such termination.*

Appendix Chapter 16A
STRUCTURAL FORCES

Division VII – EARTHQUAKE REGULATIONS FOR SEISMIC-ISOLATED STRUCTURES [FOR OSHPD1]

Code sections referenced are to the provisions in the 2001 California Building Code. Sections not modified are acceptable model code language.

SECTION 1654A – GENERAL

Every seismic-isolated structure and every portion thereof shall be designed and constructed in accordance with the requirements of this division and the applicable requirements of Chapter 16A, Part VII.

The lateral-force-resisting system and the isolation system shall be designed to resist the deformations and stresses produced by the effects of seismic ground motions as provided in this division.

Where wind forces prescribed by Chapter 16, Part III, produce greater deformations or stresses, such loads shall be used for design in lieu of the deformations and stresses resulting from earthquake forces.

SECTION 1655A – DEFINITIONS

The definitions of Section 1627A and the following apply to the provisions of this division:

DESIGN DISPLACEMENT *is the design-basis earthquake lateral displacement, excluding additional displacement due to actual and accidental torsion, required for design of the isolation system.*

DESIGN-BASIS EARTHQUAKE *is defined in Section 1631A.2.*

EFFECTIVE DAMPING *is the value of the lateral force in the isolation system, or an element thereof, divided by the corresponding lateral displacement.*

ISOLATION INTERFACE *is the boundary between the upper portion of the structure, which is isolated, and the lower portion of the structure, which moves rigidly with the ground, and any other structure.*

ISOLATION SYSTEM *is the collection of structural elements that includes all individual isolator units, all structural elements that transfer force between elements of the isolation system, and all connections to other structural elements. The isolation system also includes the wind-restraint system if such a system is used to meet the design requirements of this section.*

ISOLATOR UNIT *is a horizontally flexible and vertically stiff structural element of the isolation system that permits large lateral deformations under design seismic load. An isolator unit may be used either as part of or in addition to the weight-supporting system of the building.*

MAXIMUM CAPABLE EARTHQUAKE *is the maximum level of earthquake ground shaking that may ever be expected at the building site within the known geological framework. In Seismic Zones 3 and 4, this intensity may be taken as the level of earthquake ground motion that has a 10 percent probability of being exceeded in a 100-year time period.*

MAXIMUM DISPLACEMENT *is the maximum capable earthquake lateral displacement, excluding additional displacement due to actual and accidental torsion, required for design of the isolation system.*

TOTAL DESIGN DISPLACEMENT *is the design-basis earthquake lateral displacement, including additional displacement due to actual and accidental torsion, required for design of the isolation system, or an element thereof.*

TOTAL MAXIMUM DISPLACEMENT *is the maximum capable earthquake lateral displacement, including additional displacement due to actual and accidental torsion, required for verification of the stability of the isolation system, or elements thereof, design of building separations, and vertical load testing of isolator unit prototypes.*

WIND-RESTRAINT SYSTEM *is the collection of structural elements that provide restraint of the seismic-isolated structure for wind loads. The wind-restraint system may be either an integral part of isolator units or may be a separate device.*

SECTION 1656A – SYMBOLS AND NOTATIONS

The symbols and notations of Section 1628A and the following provisions apply to the provisions of this division:

B_D = numerical coefficient related to the effective damping of the isolation system at the design displacement, β_D, as set forth in Table A-16-C.

B_M = numerical coefficient related to the effective damping of the isolation system at the maximum displacement, β_M, as set forth in Table A-16-C.

b = the shortest plan dimension of the structure, in feet (mm), measured perpendicular to d.

C_{AD} = the seismic coefficient, C_a, as set forth in Table 16A-Q.

C_{AM} = the seismic coefficient, C_a, as set forth in Table A-16-F for shaking intensity, $M_M Z N_a$.

C_{VD} = seismic coefficient, C_v, as set forth in Table 16A-R.

C_{VM} = seismic coefficient, C_v, as set forth in Table A-16-G for shaking intensity, $M_M Z N_v$.

D_D = design displacement, in inches (mm), at the center of rigidity of the isolation system in the direction under consideration, as prescribed by Formula (58-1).

D_D' = design displacement, in inches (mm), at the center of rigidity of the isolation system in the direction under consideration, as prescribed by Formula (59-1).

D_M = maximum displacement, in inches (mm), at the center of rigidity of the isolation system in the direction under consideration, as prescribed by Formula (58-3).

D_M' = maximum displacement, in inches (mm), at the center of rigidity of the isolation system in the direction under consideration, as prescribed by Formula (59-2).

D_{TD} = *total design displacement, in inches (mm), of an element of the isolation system including both translational displacement at the center of rigidity, D_D, and the component of torsional displacement in the direction under consideration, as specified in Section 1658A.3.5.*

D_{TM} = *total maximum displacement, in inches (mm), of an element of the isolation system, including both translational displacement at the center of rigidity, D_M, and the component of torsional displacement in the direction under consideration, as specified by Section 1658A.3.3.*

d = *the longest plan dimension of the structure, in feet (mm).*

E = *vertical force component due to an earthquake loading acting in the horizontal direction.*

E_{LOOP} = *energy dissipated in kip-inches(kN-mm), in an isolator unit during a full cycle of reversible load over a test displacement range from Δ^+ to Δ^-, as measured by the area enclosed by the loop of the force-deflection curve.*

$\sum E_D$ = *total energy dissipated, in kip-inches (kN-mm), of all units of the isolation system during a full cycle of response at the design displacement, D_D.*

$\sum E_M$ = *total energy dissipated, in kip-inches (kN-mm), of all units of the isolation system during a full cycle of response at the maximum displacement, D_M.*

e = *the actual eccentricity, in feet (mm), measured in plan between the center of mass of structure above the isolation interface and the center of rigidity of the isolation system, plus accidental eccentricity, in feet (mm), taken as 5 percent of the maximum building dimension perpendicular to the direction of force under consideration.*

$F-$ = *negative force, in kips (kN), in an isolator unit during a single cycle of prototype testing at a displacement amplitude of $\Delta-$.*

$F+$ = *positive force, in kips (kN), in an isolator unit during a single cycle of prototype testing at a displacement amplitude of $\Delta+$.*

$\sum |F_D^+|_{max}$ = *sum, for all isolator units, of the absolute values of the individual isolator unit's maximum positive force in kips (kN) at positive displacement D_D. For a given isolator unit, the maximum positive force at positive displacement, D_D, is determined by comparing each of the maximum positive forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_D, and selecting the maximum positive value at positive displacement, D_D.*

$\sum |F_D^+|_{min}$ = *sum, for all isolator units, of the absolute values of the individual isolator unit's minimum positive force in kips (kN) at positive displacement D_D. For a given isolator unit, the minimum positive force at positive displacement, D_D, is determined by comparing each of the minimum positive forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_D, and selecting the minimum positive value at positive displacement, D_D.*

$\sum |F_D^-|_{max}$ = *sum, for all isolator units, of the absolute values of the individual isolator unit's maximum negative force in kips (kN) at negative displacement D_D. For a given isolator unit, the maximum negative force at negative* *displacement, D_D, is determined by comparing each of the maximum negative forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_D, and selecting the maximum negative value at negative displacement, D_D.*

$\sum |F_D^-|_{min}$ = *sum, for all isolator units, of the absolute values of the individual isolator unit's minimum negative force in kips (kN) at a negative displacement D_D. For a given isolator unit, the minimum negative force at negative displacement, D_D, is determined by comparing each of the minimum negative forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_D, and selecting the minimum negative value at negative displacement, D_D.*

$\sum |F_M^+|_{max}$ = *sum, for all isolator units, of the absolute values of the individual isolator unit's maximum positive force in kips (kN) at positive displacement D_M. For a given isolator unit, the maximum positive force at positive displacement, D_M, is determined by comparing each of the maximum positive forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_M, and selecting the maximum positive value at positive displacement, D_M.*

$\sum |F_D^+|_{min}$ = *sum, for all isolator units, of the absolute values of the individual isolator unit's minimum positive force in kips (kN) at positive displacement D_M. For a given isolator unit, the minimum positive force at positive displacement, D_M, is determined by comparing each of the minimum positive forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_M, and selecting the minimum positive value at positive displacement, D_M.*

$\sum |F_M^-|_{max}$ = *sum, for all isolator units, of the absolute values of the individual isolator unit's maximum negative force in kips (kN) at negative displacement D_M. For a given isolator unit, the maximum negative force at negative displacement, D_M, is determined by comparing each of the maximum negative forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_M and selecting the maximum negative value at negative displacement, D_M.*

$\sum |F_M^-|_{min}$ = *sum, for all isolator units, of the absolute values of the individual isolator unit's minimum negative force in kips (kN) at negative displacement D_M. For a given isolator unit, the minimum negative force at negative displacement, D_M, is determined by comparing each of the minimum negative forces that occurred during each cycle of the prototype test sequence associated with displacement increment D_M and selecting the minimum negative value at negative displacement, D_M.*

g = *gravity constant (386.4 in/sec.^{2}, or 9,810mm/sec.^{2}, for **SI**).*

k_{eff}	=	*effective stiffness of an isolator unit, in kips/inch as prescribed by Formula (65-1).*
k_{Dmax}	=	*maximum effective stiffness, in kips/inch (kN/mm), of the isolation system at the design displacement in the horizontal direction under consideration.*
k_{Mmax}	=	*maximum effective stiffness, in kips/inch (kN/mm), of the isolation system at the maximum displacement in the horizontal direction under consideration.*
k_{Dmin}	=	*minimum effective stiffness, in kips/inch (kN/mm), of the isolation system at the design displacement in the horizontal direction under consideration.*
k_{Mmin}	=	*minimum effective stiffness, in kips/inch (kN/mm), of the isolation system at the maximum displacement in the horizontal direction under consideration.*
M_M	=	*numerical coefficient related to maximum capable earthquake response as set forth in Table A-16-D.*
N_a	=	*near-source factor used in the determination of C_{AD} and C_{AM} related to both the proximity of the building or structure to known faults with magnitudes and slip rates as set forth in Tables 16A-S and 16A-U.*
N_v	=	*near-source factor used in the determination of C_{VD} and C_{VM} related to both the proximity of the building or structure to known faults with magnitudes and slip rates as set forth in Tables 16A-T and 16A-U.*
R_I	=	*numerical coefficient related to the type of lateral-force-resisting system above the isolation system as set forth in Table A-16-E for seismic-isolated structures.*
T_D	=	*effective period, in seconds, of seismic-isolated structure at the design displacement in the direction under consideration, as prescribed by Formula (58-2).*
T_M	=	*effective period, in seconds, of seismic-isolated structure at the maximum displacement in the direction under consideration, as prescribed by Formula (58-4).*
V_b	=	*the total lateral seismic design force or shear on elements of the isolation system or elements below the isolation system as prescribed by Formula (58-5).*
V_s	=	*the total lateral seismic design force or shear on elements above the isolation system as prescribed by Formula (58-8) and the limits specified in Section 1658A.*
W	=	*the total seismic dead load defined in Section 1630A.1. For design of the isolation system, W is the total seismic dead load weight of the structure above the isolation interface.*
y	=	*the distance, in feet (mm), between the center of rigidity of the isolation system rigidity and the element of interest, measured perpendicular to the direction of seismic loading under consideration.*
β_{eff}	=	*effective damping of the isolation system and isolator unit, as prescribed by Formula (65-2).*
β_D	=	*effective damping of the isolation system at the design displacement, as prescribed by Formula (65-3).*
β_M	=	*effective damping of the isolation system at the maximum displacement, as precribed by Formula (65-4).*

Δ+	=	*maximum positive displacement of an isolator unit during each cycle of prototype testing.*
Δ-	=	*maximum negative displacement of an isolator unit during each cycle of prototype testing.*

SECTION 1657A – CRITERIA SELECTION

1657A.1 Basis for Design. *The procedures and limitations for the design of seismic-isolated structures shall be determined considering zoning, site characteristics, vertical acceleration, cracked section properties of concrete and masonry members, occupancy, configuration, structural system and height in accordance with Section 1629A, except as noted below.*

1657A.2 Stability for the Design System. *The stability of the vertical load-carrying elements of the isolation system shall be verified by analysis and test, as required, for lateral seismic displacement equal to the total maximum displacement.*

1657A.3 Occupancy Categories. *The importance factor, I, for a seismic-isolated building shall be taken as 1.0 regardless of occupancy category. [For OSHPD 1:] The importance factor, I_p, for parts and portions of a seismic-isolated building shall be the same as that required for a fixed-base building of the same occupancy category.*

1657A.4 Configuration Requirements. *Each structure shall be designated as being regular or irregular on the basis of the structural configuration above the isolation system, in accordance with Section 1629A.5.*

1657A.5 Selection of Lateral Response Procedure.

1657A.5.1 General. *Seismic-isolated structures shall be designed using the dynamic lateral response procedure of Section 1659A.*

1657A.5.1.1 Period separation. *In each principal direction, the fundamental period, T of the superstructure, computed in accordance with Formula (30-10), assuming that the structure is fixed at the isolation interface, shall not exceed the isolated-structure period, T_M.*

1657A.5.2 Static analysis. *The static lateral response procedure of Section 1658A shall be used to establish minimum criteria only, and not be used for design purposes unless these minimum requirements exceed calculated values from the dynamic analysis.*

1657A.5.3 Dynamic analysis. *The dynamic lateral response procedure of Section 1659A shall be used for design of seismic-isolated structures as specified below:*

1. ***Response spectrum analysis.*** *Response spectrum analysis may be used for design of a seismic-isolated structure, provided:*

1.1 The structure is located on Soil Profile Type S_A, S_B, S_C or S_D.
1.2 The isolation system is defined by all of the following attributes:
1.2.1 The effective stiffness of the isolation system at the design displacement is greater than one half of the effective stiffness at 20 percent of the design displacement.
1.2.2 The isolation system is capable of producing a restoring force, as specified in Section 1661A.2.4.
1.2.3 The isolation system has force-deflection properties which are independent of the rate of loading.
1.2.4 The isolation system has force-deflection properties which are independent of vertical load and bilateral load.
1.2.5 The isolation system does not limit the total maximum displacement to less than C_{VM}/C_{VD} times the total design displacement.
1.3 The near-source factor, N_a, is equal to 1.0.

*2. **Time-history analysis.** Time-history analysis may be used for design of any seismic-isolated structure and shall be used for design of all seismic-isolated structures not meeting the criteria of Section 1657A.5.3, Item 1.*

*3. **Site-specific design spectra.** Site-specific ground motion spectra of the design-basis earthquake and the maximum capable earthquake, developed in accordance with Sections 1631A.2 and 1637A, shall be used for design and analysis of all seismic-isolated structures.*

SECTION 1658A - STATIC LATERAL RESPONSE PROCEDURE

1658A.1 General. *Except as provided in Section 1659A, every seismic-isolated structure, or portion thereof, shall be designed and constructed to resist minimum earthquake displacements and forces as specified by this section and the applicable requirements of Section 1630A.*

1658A.2 Deformation Characteristics of the Isolation System. *Minimum lateral earthquake design displacements and forces on seismic-isolated structures shall be based on the deformation characteristics of the isolation system.*

The deformation characteristics of the isolation system shall explicitly include the effects of the wind-restraint system if such a system is used to meet the design requirements of this document.

The deformation characteristics of the isolation system shall be based on properly substantiated tests performed in accordance with Section 1665A.

1658A.3 Minimum Lateral Displacements.

1658A.3.1 Design displacement. *The isolation system shall be designed and constructed to withstand minimum lateral earthquake displacements which act in the* *direction of each of the main horizontal axes of the structure in accordance with the formula:*

$$D_D = \frac{\left(\frac{g}{4\pi^2}\right) C_{VD} T_D}{B_D} \qquad (58\text{-}1)$$

1658A.3.2 Effective period at the design displacement. *The effective period of the isolated structure at the design displacement, TD, shall be determined using the deformational characteristics of the isolation system in accordance with the formula:*

$$T_D = 2\pi\sqrt{\frac{W}{k_{D\,\min}\, g}} \qquad (58\text{-}2)$$

1658A.3.3 Maximum displacement. *The maximum displacement of the isolation system, DM, in the most critical direction of horizontal response shall be calculated in accordance with the formula:*

$$D_M = \frac{\left(\frac{g}{4\pi^2}\right) C_{VM} T_M}{B_M} \qquad (58\text{-}3)$$

1658A.3.4 Effective period at the maximum displacement. *The effective period of the isolated structure at the maximum displacement, TM, shall be determined using the deformational characteristics of the isolations system in accordance with the formula:*

$$T_M = 2\pi\sqrt{\frac{W}{k_{M\,\min}\, g}} \qquad (58\text{-}4)$$

1658A.3.5 Total displacement. *The total design displacement, D_{TD}, and the total maximum displacement, D_{TM}, of elements of the isolation system shall include additional displacement due to actual and accidental torsion calculated considering the spatial distribution of the lateral stiffness of the isolation system and the most disadvantageous location of mass eccentricity.*

The total design displacement, D_{TD}, and the total maximum displacement, D_{TM}, of elements of an isolation system with uniform spatial distribution of lateral stiffness shall not be taken as less than that prescribed by the formulas:

$$D_{TD} = D_D\left[1 + y\,\frac{12e}{b^2 + d^2}\right] \qquad (58\text{-}5)$$

$$D_{TM} = D_M\left[1 + y\,\frac{12e}{b^2 + d^2}\right] \qquad (58\text{-}6)$$

The total design displacement, DTD, and the total maximum displacement, DTM, may be taken as less than the value prescribed by Formulas (58-5) and (58-6), but not less than

1.1 times DD and 1.1 times DM, respectively, provided the isolation system is shown by calculation to be configured to resist torsion accordingly.

1658A.4 Minimum Lateral Forces.

1658A.4.1 Isolation system and structural elements at or below the isolation system. *The isolation system, the foundation, and all structural elements below the isolation system shall be designed and constructed to withstand a minimum lateral seismic force, Vb, using all of the appropriate provisions for a nonisolated structure where:*

$$V_b = k_{Dmax} D_D \qquad (58\text{-}7)$$

1658A.4.2 Structural elements above the isolation system. *The structure above the isolation system shall be designed and constructed to withstand a minimum shear force, Vs, using all of the appropriate provisions for a nonisolated structure where:*

$$V_s = \frac{k_{D\max} D_D}{R_I} \qquad (58\text{-}8)$$

The R_I factor shall be based on the type of lateral-force-resisting system used for the structure above the isolation system.

1658A.4.3 Limits on V_s. *The value of V_s shall not be taken as less than the following:*

1. *The lateral seismic force required by Chapter 16, Division III, for a fixed-base structure of the same weight, W, and a period equal to the isolated period, T_D, using the importance factor, I, given in Table 16A-K.*
2. *The base shear corresponding to the design wind load.*
3. *The lateral seismic force required to fully activate the isolation system factored by 1.5 (e.g., one and one-half times the yield level of a softening system, the ultimate capacity of a sacrificial wind-restraint system or the static friction level of a sliding system).*

1658A.5 Vertical Distribution of Force. *The total force shall be distributed over the height of the structure above the isolation interface in accordance with the formula:*

$$F_x = \frac{V_s w_x h_x}{\sum_{i=1}^{n} w_i h_i} \qquad (58\text{-}9)$$

At each level designated as x, the force F_x shall be applied over the area of the building in accordance with the mass distribution at the level. Stresses in each structural element shall be calculated as the effect of force, F_x, applied at the appropriate levels above the base.

1658A.6 Drift Limits. *The maximum interstory drift ratio of the structure above the isolation system shall not exceed $0.010/R_I$.*

SECTION 1659A – DYNAMIC LATERAL-RESPONSE PROCEDURE

1659A.1 General. *As required by Section 1657A, every seismic-isolated structure, or portion thereof, shall be designed and constructed to resist earthquake displacements and forces as specified in this section and the applicable requirements of Section 1631A.*

1659A.2 Isolation System and Structural Elements below the Isolation System. *The total design displacement of the isolation system shall not be taken as less than 90 percent of D_{TD} as specified by Section 1658A.3.3.*

The total maximum displacement of the isolation system shall not be taken as less than 80 percent of D_{TM} as prescribed by Formula (58-6).

The design lateral shear force on the isolation system and structural elements below the isolation system shall not be taken as less than 90 percent of V_b as prescribed by Formula (58-7).

The limits of the first and second paragraphs shall be evaluated using values of D_{TD} and D_{TM} determined in accordance with Section 1658A.3, except that D_D' may be used in lieu of D_D and D_M' may be used in lieu of D_M, where D_D' and D_M' are prescribed by the formulas:

$$D_D' = \frac{D_D}{\sqrt{1+\left(\frac{T}{T_D}\right)^2}} \qquad (59\text{-}1)$$

$$DM' = \frac{DM}{\sqrt{1+\left(\frac{T}{T_M}\right)^2}} \qquad (59\text{-}2)$$

and T is the elastic, fixed-base period of the structure above the isolation system, as determined only by Formula (30-4) of Section 1630A.

1659A.3 Structural Elements above the Isolation System. *The design lateral shear force on the structure above the isolation system, if regular in configuration, shall not be taken as less than 80 percent of V_S as prescribed by Formula (58-8) or less than the limits specified by Section 1658A.4.3.*

> ***EXCEPTION:*** *The design lateral shear force on the structure above the isolation system, if regular in configuration, may be taken as less than 80 percent, but not less than 60 percent, of VS provided time history analysis is used for design of the structure.*

The design lateral shear force on the structure above the isolation system, if irregular in configuration, shall not be taken as less than VS as prescribed in Formula (58-8) or less than the limits specified by Section 1658A.4.3.

> ***EXCEPTION:*** *The design lateral shear force on the structure above the isolation system, if irregular in configuration, may be taken as less than 100 percent, but not less than 80 percent, of VS, provided time-history analysis is used for design of the structure.*

1659A.4 Ground Motion.

1659A.4.1 Design spectra. *Properly substantiated, site-specific spectra are required for design of all structures.*

A design spectrum shall be constructed for the design-basis earthquake. This design spectrum shall not be taken as less than the response spectrum given in Figure 16A-3 of Chapter 16, Division III, where the values of C_a shall be taken as equal to C_{AD} and C_v shall be taken as equal to C_{VD}.

> ***EXCEPTION:*** *If a site-specific spectrum is calculated for the design-basis earthquake, then the design spectrum may be taken as less than 100 percent, but not less than 80 percent of the response spectrum given in Figure 16A-3 of Chapter 16, Division III, where the values of C_a shall be taken as equal to C_{AD} and C_v shall be taken as equal to C_{VD}.*

A design spectrum shall be constructed for the maximum capable earthquake. This spectrum shall not be taken as less than the spectrum given in Figure 16A-3 of Chapter 16, Division III where the values of C_a shall be taken as equal to C_{AM} and C_v shall be taken as equal to C_{VM}. This spectrum shall be used to determine the total maximum displacement and overturning forces for design and testing of the isolation system.

> ***EXCEPTION:*** *If a site-specific spectrum is calculated for the maximum capable earthquake, then the design spectrum may be taken as less than 100 percent, but not less than 80 percent of the response spectrum given in Figure 16A-3 of Chapter 16, Division III, where the value of C_a shall be taken as equal to C_{AM} and C_v shall be taken as equal to C_{VM}.*

1659A.4.2 Time histories. *Pairs of appropriate horizontal ground-motion time-history components shall be selected and scaled from not less than three recorded events. Appropriate time histories shall have magnitudes, fault distances and source mechanisms that are consistent with those that control the design-basis earthquake (or maximum capable earthquake). Where three appropriate recorded ground motion time history pairs are not available, appropriate simulated ground motion time history pairs may be used to make up the total number required. For each pair of horizontal ground-motion components, the square root sum of the squares (SRSS) of the 5 percent-damped spectrum of the scaled horizontal components shall be constructed. The motions shall be scaled such that the average value of the SRSS spectra does not fall below 1.3 times the 5 percent-damped spectrum of the design- basis earthquake (or maximum capable earthquake) by more than 10 percent for periods from $0.5T_D$ seconds to $1.25T_M$ seconds. The SRSS of the time history components shall be equal to or greater than the 5 percent damped spectra at the isolated period T_I, either T_D or T_M.*

The duration of the time histories shall be consistent with the magnitude and source characteristics of the design-basis earthquake (or maximum capable earthquake).

Time histories developed for sites with a Near-Source Factor, N_a, greater than 1.0 shall incorporate near-source phenomena.

1659A.5 Mathematical Model.

1659A.5.1 General. *The mathematical models of the isolated structure, including the isolation system, the lateral-force-resisting system and other structural elements, shall* *conform to Section 1631A.3 and to the requirements of Sections 1659A.5.2 and 1659A.5.3 below.*

1659A.5.2 Isolation system. *The isolation system shall be modeled using deformational characteristics developed and verified by test in accordance with the requirements of Section 1658A.2.*

The isolation system shall be modeled with sufficient detail to:

1. *Account for the spatial distribution of isolator units;*
2. *Calculate translation, in both horizontal directions, and torsion of the structure above the isolation interface, considering the most disadvantageous location of mass eccentricity;*
3. *Assess overturning/uplift forces on individual isolator units; and*
4. *Account for the effects of vertical load, bilateral load and/or the rate of loading if the force deflection properties of the isolation system are dependent on one ore more of these attributes.*

1659A.5.3 Isolated structure.

1659A.5.3.1 Displacement. *The maximum displacement of each floor and the total design displacement and total maximum displacement across the isolation system shall be calculated using a model of the isolated structure that incorporates the force-deflection characteristics of nonlinear elements of the isolation system and the lateral-force-resisting system.*

Lateral-force-resisting systems with nonlinear elements include, but are not limited to, irregular structural systems designed for a lateral force less than V_s as prescribed by Formula (58-8) and the limits specified by Section 1658A.4.3, and regular structural systems designed for a lateral force less than 80 percent of V_s.

1659A.5.3.2 Forces and displacements in key elements. *Design forces and displacements in key elements of the lateral-force-resisting system may be calculated using a linear elastic model of the isolated structure, provided:*

1. *Pseudo-elastic properties assumed for nonlinear isolation system components are based on the maximum effective stiffness of the isolation system.*
2. *All key elements of the lateral-force-resisting system are linear.*

1659A.6 Description of Analysis Procedures.

1659A.6.1 General. *A response spectrum analysis or a time-history analysis, or both, shall be performed in accordance with Sections 1631A.4 and 1631A.5 and the requirements of this section.*

1659A.6.2 Input earthquake. *The design-basis earthquake shall be used to calculate the total design displacement of the isolation system and the lateral forces and displacements of the isolated structure. The maximum capable earthquake shall be used to calculate the total maximum displacement of the isolation system.*

1659A.6.3 Response spectrum analysis. *Response spectrum analysis shall be performed using a modal damping value for the fundamental mode in the direction of interest not greater than the effective damping of the isolation system or 30 percent of critical, whichever is less. Modal damping values for higher modes shall be selected consistent with those appropriate for response spectrum analysis of the structure above the isolation system on a fixed base.*

Response spectrum analysis used to determine the total design displacement and the total maximum displacement shall include simultaneous excitation of the model by 100 percent of the most critical direction of ground motion and 30 percent of the ground motion on the orthogonal axis. The maximum displacement of the isolation system shall be calculated as the vectorial sum of the two orthogonal displacements.

1659A.6.4 Time-history analysis. *Time-history analysis shall be performed with at least three appropriate pairs of horizontal time-history components, as defined in Section 1659A.4.2.*
Each pair of time histories shall be applied simultaneously to the model, considering the most disadvantageous location of mass eccentricity. The maximum displacement of the isolation system shall be calculated from the vectorial sum of the two orthogonal displacements at each time step.
The parameter of interest shall be calculated for each time-history analysis. If three time-history analyses are performed, then the maximum response of the parameter of interest shall be used for design. If seven or more time-history analyses are performed, then the average value of the response parameter of interest may be used for design.

1659A.7 Design Lateral Force.

1659A.7.1 Isolation system and structural elements at or below the isolation system. *The isolation system, foundation and all structural elements below the isolation system shall be designed using all of the appropriate provisions for a nonisolated structure and the forces obtained from the dynamic analysis.*

1659A.7.2 Structural elements above the isolation system. *Structural elements above the isolation system shall be designed using the appropriate provisions for a nonisolated structure and the forces obtained from the dynamic analysis divided by a factor of R_I. The R_I factor shall be based on the type of lateral-force-resisting system used for the structure above the isolation system.*

1659A.7.3 Scaling of results. *When the factored lateral shear force on structural elements, determined using either response spectrum or time-history analysis, is less than minimum level prescribed by Sections 1659A.1 and 1659A.2, then all response parameters, including member forces and moments shall be adjusted upward proportionally.*

1659A.8 Drift limits. *Maximum interstory drift corresponding to the design lateral force, including displacement due to vertical deformation of the isolation system, and uplift and/or rocking shall not exceed the following limits:*

1. The maximum interstory drift ratio of the structure above the isolation system, calculated by response spectrum analysis, shall not exceed $0.015/R_I$.

2. The maximum interstory drift ratio of the structure above the isolation system, calculated by time-history analysis considering the force-deflection characteristics of nonlinear elements of the lateral-force-resisting system, shall not exceed $0.020/R_I$.

The secondary effects of the maximum capable earthquake lateral displacement, Δ, of the structure above the isolation system combined with gravity forces shall be investigated if the interstory drift ratio exceeds.$0.010/R_I$.

SECTION 1660A – LATERAL LOAD ON ELEMENTS OF STRUCTURES AND NONSTRUCTURAL COMPONENTS SUPPORTED BY STRUCTURES

1660A.1 General. *Parts and portions of an isolated structure, permanent nonstructural components and the attachments to them, and the attachments for permanent equipment supported by a structure shall be designed to resist seismic forces and displacements as prescribed in this section and the applicable requirements of Section 1632A, considering the appropriate Importance Factor, I_p, defined in Table 16A-K.*

1660A.2 Forces and Displacements.

1660A.2.1 Components at or above the isolation interface. *Elements of seismic-isolated structures and nonstructural components, or portions thereof, which are at or above the isolation interface, shall be designed to resist a total lateral seismic force equal to the maximum dynamic response of the element or component under consideration.*

> ***EXCEPTION:*** *Elements of seismic-isolated structures and nonstructural components, or portions thereof, may be designed to resist total lateral seismic force as prescribed by Formula (32-1) or (32-2) of Section 1632A.*

1660A.2.2 Components that cross the isolation interface. *Elements of seismic-isolated structures and nonstructural components, or portions thereof, that cross the isolation interface shall be designed to withstand the total maximum displacement.*

1660A.2.3 Components below the isolation interface. *Elements of seismic-isolated structures and nonstructural components, or portions thereof, which are below the isolation interface shall be designed and constructed in accordance with the requirements of Section 1632A.*

SECTION 1661A - DETAILED SYSTEMS REQUIREMENTS

1661A.1 General. *The isolation system and the structural system shall comply with the requirements of Section 1633A and the material requirements of Chapters 19 through 23. In addition, the isolation system shall comply with the detailed system requirements of this section and the structural system shall comply with the detailed system requirements of this section and the applicable portions of Section 1633A.*

1661A.2 Isolation System.

1661A.2.1 Environmental conditions. *In addition to the requirements for vertical and lateral loads induced by wind and earthquake, the isolation system shall be designed with consideration given to other environmental conditions including aging effects, creep, fatigue, operating temperature and exposure to moisture or damaging substances.*

1661A.2.2 Wind forces. *Isolated structures shall resist design wind loads at all levels above the isolation interface in accordance with the general wind design provisions. At the isolation interface, a wind restraint system shall be provided to limit lateral displacement in the isolation system to a value equal to that required between floors of the structure above the isolation interface.*

1661A.2.3 Fire resistance. *Fire resistance for the isolation system shall meet that required for the building columns, walls or other structural elements in which it is installed.*
Isolator systems required to have a fire-resistive rating shall be protected with approved materials or construction assemblies designed to provide the same degree of fire resistance as the structural element in which it is installed when tested in accordance with UBC Standard 7-1. See Section 703.2.

Such isolation system protection applied to isolator units shall be capable of retarding the transfer of heat to the isolator unit in such a manner that the required gravity load-carrying capacity of the isolator unit will not be impaired after exposure to the standard time-temperature curve fire test prescribed in UBC Standard 7-1 for a duration not less than that required for the fire-resistive rating of the structural element in which it is installed.
Such isolation system protection applied to isolator units shall be suitably designed and securely installed so as not to dislodge, loosen, sustain damage, or otherwise impair its ability to accommodate the seismic movements for which the isolator unit is designed and to maintain its integrity for the purpose of providing the required fire-resistive protection.

1661A.2.4 Lateral restoring force. *The isolation system shall be configured to produce a restoring force such that the lateral force at the total design displacement is at least 0.025W greater than the lateral force at 50 percent of the total design displacement.*

> ***EXCEPTION:*** *The isolation system need not be configured to produce a restoring force, as required above, provided the isolation system is capable of remaining stable under full vertical load and accommodating a total maximum displacement equal to the greater of either 3.0 times the total design displacement 36 C_{VM}, inches (For SI: 914.4 C_{VM}, mm).*

1661A.2.5 Displacement restraint. *The isolation system may be configured to include a displacement restraint that limits lateral displacement due to the maximum capable earthquake to less than C_{VM}/C_{VD} times the total design displacement, provided that the seismic-isolated structure is designed in accordance with the following criteria when more stringent than the requirements of Section 1629A.*

1. Maximum capable earthquake response is calculated in accordance with the dynamic analysis requirements of Sections 1631A and 1659A, explicitly considering the nonlinear characteristics of the isolation system and the structure above the isolation system.

2. The ultimate capacity of the isolation system and structural elements below the isolation system shall exceed the strength and displacement demands of the maximum capable earthquake.

3. The structure above the isolation system is checked for stability and ductility demand of the maximum capable earthquake.

4. The displacement restraint does not become effective at a displacement less than 0.75 times the total design displacement unless it is demonstrated by analysis that earlier engagement does not result in unsatisfactory performance.

1661A.2.6 Vertical load stability. *Each element of the isolation system shall be designed to be stable under the maximum vertical load, 1.2D + 1.0L + $|E|_{max}$ and the minimum vertical load, 0.80D - $|E|_{min}$, at a horizontal displacement equal to the total maximum displacement. The vertical earthquake load on an individual isolator unit due to overturning, $|E|_{max}$ and $|E|_{min}$, shall be based on peak response due to the maximum capable earthquake. When considering the load combinations above, the load combinations of Section 1612A and the earthquake loads of Section 1630A.1.1 need not be considered.*

1661A.2.7 Overturning. *The factor of safety against global structural overturning at the isolation interface shall not be less than 1.0 for required load combinations. All gravity and seismic loading conditions shall be investigated. Seismic forces for overturning calculations shall be based on the maximum capable earthquake and W shall be used for the vertical restoring force.*

Local uplift of individual elements is permitted provided the resulting deflections do not cause overstress or instability of the isolator units or other building elements. The effects of uplift and/or rocking shall be explicitly accounted for in the analysis and in the testing of the isolator units.

1661A.2.8 Instrumentation, Inspection and replacement.
1. Access for inspection and replacement of all components of the isolation system shall be provided.
2. The architect or engineer of record or a person designated by the architect or engineer of record shall complete a final series of inspections or observations of building separation areas and of components that cross the isolation interface prior to the issuance of the certificate of occupancy for the seismic-isolated building. Such inspections and observations shall indicate that as-built conditions allow for free and unhindered displacement of the structure to maximum design levels and that all components that cross the isolation interface as installed, are able to accommodate the stipulated displacements.

*3. Seismic-isolated buildings shall have a periodic monitoring, inspection and maintenance program for the isolation system established by the * * * engineer responsible for the design of the system. The objective of such a program shall be to ensure that all elements of the isolation system are able to perform to minimum design levels at all times. These programs shall be submitted for approval with the plans and specifications and shall be a condition of occupancy for the structure.*
4. Remodeling, repair or retrofitting at the isolation system interface, including that of components that cross the isolation interface, shall be performed under the direction of an architect or engineer licensed in the appropriate disciplines and experienced in the design and construction of seismic-isolated structures.
5. A proposal for instrumentation and equipment specifications shall be forwarded to the enforcement agency for approval. Motion measuring instruments shall be located within the building and at levels immediately above and below the isolators. The owner of the building is responsible for the implementation of the instrumentation program. Maintenance of the instrumentation and removal and processing of the records shall be the responsibility of the enforcement agency or its designated agent.
6. After every significant seismic event, the owner shall retain a structural engineer to make an inspection of the structural system. The inspection shall consist of viewing the performance of the building, reviewing the strong motion records, and a visual examination of the isolators and their connections for deterioration, offset or physical damage. A report for each inspection, including conclusions on the continuing adequacy of the structural system, shall be submitted as required to the enforcement agency.

1661A.2.9 Quality control. *A quality control testing program for isolator units shall be established by the engineer responsible for the structural design and approved by the enforcement agency. The quality control testing program shall include provisions for both prototype and production isolator units.*

1661A.3 Structural System.

1661A.3.1 Horizontal distribution of force. *A horizontal diaphragm or other structural elements shall provide continuity above the isolation interface and shall have adequate strength and ductility to transmit forces (due to nonuniform ground motion) from one part of the building to another.*

1661A.3.2 Building separations. *Minimum separations between the isolated building and the surrounding retaining walls or other fixed obstructions shall not be less than the total maximum displacement.*

The separation requirements for the building above the isolation system and adjacent buildings shall be the sum of the factored displacements for each building. The factors to be used in determining separations shall be:

For elastic deformations resulting from the dynamic analysis using the Maximum Capable Earthquake unmodified by R_I or, 0.7R times the elastic deformations of an adjacent fixed base structure resulting from an equivalent static analysis.

SECTION 1662A – NONBUILDING STRUCTURES

Nonbuilding structures shall be designed in accordance with the requirements of Section 1634A using design displacements and forces calculated in accordance with Section 1658A or 1659A.

SECTION 1663A – FOUNDATIONS

Foundations shall be designed and constructed in accordance with the requirements of Chapter 18A using design forces calculated in accordance with Section 1658A or 1659A.

SECTION 1664A – DESIGN AND CONSTRUCTION REVIEW

1664A.1 General. *The design review shall be the responsibility of the enforcement agency. The enforcement agency may at its discretion require the owner of the facility to retain an independent team to review and report on the isolation system design, site conditions and/or building configurations. The team shall serve in an advisory capacity to provide technical evaluations to the enforcement agency. Members of the independent team shall be approved by the enforcement agency.*

1664A.2 Isolation system. *Isolation system design review shall include, but not be limited to, the following:*
1. *Review of site-specific seismic criteria, including the development of site-specific spectra and ground motion time histories, and all other design criteria developed specifically for the project.*
2. *Review of the preliminary design, including the determination of the total design displacement of the isolation system design displacement and lateral force design level.*
3. *Overview and observation of prototype testing (Section 1665A).*
4. *Review of the final design of the entire structural system and all supporting analyses.*
5. *Review of the isolation system quality control testing program (Section 1661A.2.9).*

The engineer of record shall submit with the plans and calculations a statement by all members of the independent engineering team stating that the above has been completed.

1664A.3 Inspection. *A special inspector shall be hired by the owner and approved by the structural engineer of record and the enforcement agency to observe all prototype and production testing and file all reports required by Part 1 of the California Building Standards Administrative Code.*

SECTION 1665A - REQUIRED TESTS OF ISOLATION SYSTEM

1665A.1 General. *The deformation characteristics and damping values of the isolation system used in the design and analysis of seismic-isolated structures shall be based on the following tests of a selected sample of the components prior to construction.*

The isolation system components to be tested shall include the wind restraint system if such systems are used in the design.

The tests specified in this section are for establishing and validating the design properties of the isolation system, and shall not be considered as satisfying the manufacturing quality control tests of Section 1661A.2.9.

1665A.2 Prototype Tests.

1665A.2.1 General. *Prototype tests shall be performed separately on two full-size specimens or sets of specimens, as appropriate, of each type and size of isolator unit of the isolation system. The test specimens shall include the wind restraint system, as well as individual isolator units, if such systems are used in the design. Specimens tested shall not be used for construction.*

1665A.2.2 Record. *For each cycle of tests the force-deflection behavior of the test specimen shall be recorded.*

1665A.2.3 Sequence and cycles.
The following sequence of tests shall be performed for the prescribed number of cycles at a vertical load equal to the average D + 0.5L on all isolator units of a common type and size:

1. *Twenty fully reversed cycles of loading at a lateral force corresponding to the wind design force.*
2. *Three fully reversed cycles of loading at each of the following increments of displacement: 0.2 D_D, 0.5 D_D and 1.0 D_D, 1.0 D_M.*
3. *Three fully reversed cycles at the total maximum displacement, 1.0D_{TM}.*
4. *($15C_{VD}/C_{VA}B_D$), but not less than 10, fully reversed cycles of loading at 1.0 times the total design displacement, 1.0D_{TD}.*

If an isolator unit is also a vertical load-carrying element, then Item 2 of the sequence of cyclic tests specified above shall be performed for two additional vertical load cases:

$$(1) 1.2D + 0.5L + |E|$$

$$(2) 0.8D - |E|$$

where D and L are defined in Chapter 16, Division III. The vertical test load on an individual isolator unit shall include the load increment due to earthquake overturning, |E|, and shall be equal to or greater than the peak earthquake vertical force response *corresponding to the test displacement being evaluated. In these tests, the combined vertical load shall be taken as the typical or average downward force on all isolator units of a common size and type. When considering the load combinations above, the load combinations of Section 1612A and the earthquake loads of Section 1630A.1.1 need not be considered.*

1665A.2.4 Units dependent on loading rates. *If the force-deflection properties of the isolator units are dependent on the rate of loading, then each set of tests specified in Section 1665A.2.3 shall be performed dynamically at a frequency equal to the inverse of the effective period, T_D, of the isolated structure.*
If reduced-scale prototype specimens are used to quantify rate-dependent properties of isolators, the reduced-scale prototype specimens shall be of the same type and material and be manufactured with the same processes and quality as full-scale prototypes, and shall be tested at a frequency that represents full-scale prototype loading rates.

The force-deflection properties of an isolator unit shall be considered to be dependent on the rate of loading if there is greater than a plus minus 10 percent difference in the effective stiffness at the design displacement when tested at a frequency equal to the inverse of the effective period, T_D, of the isolated structure and when tested at any frequency in the range of 0.1 to 2.0 times the inverse of the effective period, T_D, of the isolated structure.

1665A.2.5 Units dependent on bilateral load. *If the force-deflection properties of the isolator units are dependent on bilateral load, then the tests specified in Sections 1665A.2.3 and 1665A.2.4 shall be augmented to include bilateral load at increments of the total design displacement 0.25 and 1.0, 0.50 and 1.0, and 0.75 and 1.0, and 1.0 and 1.0.*

> ***EXCEPTION:*** *If reduced-scale prototype specimens are used to quantify bilateral-load-dependent properties, then such scaled specimens shall be of the same type and material, and manufactured with the same processes and quality as full-scale prototypes.*

The force-deflection properties of an isolator unit shall be considered to be dependent on bilateral load, if the bilateral and unilateral force-deflection properties have greater than a plus or minus 10 percent difference in effective stiffness at the design displacement.

1665A.2.6 Maximum and minimum vertical load. *Isolator units that carry vertical load shall be statically tested for the maximum and minimum vertical load, at the total maximum displacement. In these tests, the combined vertical loads of 1.2D + 1.0L + $|E|_{max}$ shall be taken as the maximum vertical force, and the combined vertical load of 0.8D - $|E|_{min}$ shall be taken as the minimum vertical force, on any one isolator unit of a common type and size. The vertical load on an individual isolator unit shall include the load increment due to earthquake overturning, $|E|_{max}$ and $|E|_{min}$, and shall be based on peak response due to the maximum capable earthquake.*

1665A.2.7 Sacrificial wind-restraint systems. *If a sacrificial wind-restraint system is to be utilized, then the ultimate capacity shall be established by test.*

1665A.2.8 Testing similar units. *The prototype tests are not required if an isolator unit is of similar dimensional characteristics and of the same type and material as the prototype isolator unit that has been previously tested using the specified sequence of tests.*

1665A.3 Determination of Force-deflection Characteristics. *The force-deflection characteristics of the isolation system shall be based on the cyclic load tests of isolator prototypes specified in Section 1665A.2.3.*

As required, the effective stiffness of an isolator unit, k_{eff}, shall be calculated for each cycle of loading by the formula:

$$k_{eff} = \frac{F^{+} - F^{-}}{\Delta^{+} - \Delta^{-}} \qquad (65\text{-}1)$$

where F+ and F- are the positive and negative forces at Δ+ and Δ-, respectively.
As required, the effective damping (β_{eff}) of an isolator unit shall be calculated for each cycle of loading by the formula:

$$\beta_{eff} = \frac{2}{\pi}\left[\frac{E_{Loop}}{k_{eff}\left(\left|\Delta^{+}\right| + \left|\Delta^{-}\right|\right)^{2}}\right] \qquad (65\text{-}2)$$

where the energy dissipated per cycle of loading, $_{Eloop}$, and the effective stiffness, k_{eff}, shall be based on test displacements of Δ+ and Δ-.

1665A.4 System Adequacy. *The performance of the test specimens shall be assessed as adequate if the following conditions are satisfied:*

1. The force-deflection plots of all tests specified in Section 1665A.2 have a positive incremental force-carrying capacity.

2. For each increment of test displacement specified in Section 1665A.2.3, Item 2, and for each vertical load case specified in Section 1665A.2.3:

> *2.1 There is no greater than a plus or minus 10 percent difference between the effective stiffness at each of the three cycles of test and the average value of effective stiffness for each test specimen.*
>
> *2.2 There is no greater than a 10 percent difference in the average value of effective stiffness of the two test specimens of a common type and size of the isolator unit over the required three cycles of test.*

3. For each specimen there is no greater than a plus or minus 20 percent change in the initial effective stiffness of each test specimen over the ($15C_{VD}/C_{VA}B_D$), but not less than 10, cycles of the test specified in Section 1665A.2.3, Item 4.

4. For each specimen there is no greater than a 20 percent decrease in the initial effective damping over for the ($15C_{VD}/C_{VA}B_D$) but not less than 10, cycles of the test specified in Section 1665A.2.3, Item 4.

5. All specimens of vertical load-carrying elements of the isolation system remain stable at the total maximum displacement for static load as prescribed in Section 1665A.2.6.

1665A.5 Design Properties of the Isolation System.

1665A.5.1 Maximum and minimum effective stiffness. *At the design displacement, the maximum and minimum effective stiffnesses of the isolation system, k_{Dmax} and k_{Dmin}, shall be based on the cyclic tests of Section 1665A.2.3 and calculated by the formulas:*

$$k_{D\max} = \frac{\sum \left|F_D^+\right|_{\max} + \sum \left|F_D^-\right|_{\max}}{2D_D} \qquad (65\text{-}3)$$

$$k_{D\min} = \frac{\sum \left|F_D^+\right|_{\min} + \sum \left|F_D^-\right|_{\min}}{2D_D} \qquad (65\text{-}4)$$

At the maximum displacement, the maximum and minimum effective stiffness of the isolation system, k_{Mmax} and k_{Mmin}, shall be based on the cyclic tests of Section 1665A.2.3 and calculated by the formulas:

$$k_{M\max} = \frac{\sum \left|F_M^+\right|_{\max} + \sum \left|F_M^-\right|_{\max}}{2D_M} \qquad (65\text{-}5)$$

$$k_{M\min} = \frac{\sum \left|F_M^+\right|_{\min} + \sum \left|F_M^-\right|_{\min}}{2D_M} \qquad (65\text{-}6)$$

For isolator units that are found by the tests of Sections 1665A.2.3, 1665A.2.4 and 1665A.2.5 to have force-deflection characteristics which vary with vertical load, rate of loading or bilateral load, respectively, the values of k_{Dmax} and k_{Mmax} shall be increased and the values of k_{Dmin} and k_{Mmin} shall be decreased, as necessary, to bound the effects of measured variation in effective stiffness.

1665A.5.2 Effective damping. *At the design displacement, the effective damping of the isolation system, β_D, shall be based on the cyclic tests of Section 1665A.2.3 and calculated by the formula:*

$$\beta_D = \frac{1}{2\pi}\left[\frac{\sum E_D}{k_{D\max} D^2{}_D}\right] \qquad (65\text{-}7)$$

In Formula (65-7), the total energy dissipated in the isolation system per cycle of design displacement response, $\sum E_D$, shall be taken as the sum of the energy dissipated per cycle in all isolator units measured at test displacements Δ+ and Δ-, that are equal in magnitude to the design displacement, D_D.

At the maximum displacement, the effective damping of the isolation system, β_M, shall be based on the cyclic tests of Section 1665A.2.3 and calculated by the formula:

$$\beta_D = \frac{1}{2\pi}\left[\frac{\sum E_M}{k_{M\max} D^2{}_M}\right] \qquad \text{(65-8)}$$

In Formula (65-8), the total energy dissipated in the isolation system per cycle of response, E_M, shall be taken as the sum of the energy dissipated per cycle in all isolator units measured at test displacements, Δ+ and Δ-, that are equal in magnitude to the maximum displacement, D_M.

TABLE A-16-C – DAMPING COEFFICIENTS, B_D AND B_M

TABLE A-16-D – MAXIMUM CAPABLE EARTHQUAKE RESPONSE COEFFICIENT, M_M

TABLE A-16-E – STRUCTURAL SYSTEMS ABOVE THE ISOLATION INTERFACE[1]

BASIC STRUCTURAL SYSTEM[2]	LATERAL-FORCE-RESISTING SYSTEM DESCRIPTION	R_I	HEIGHT LIMIT FOR SEISMIC ZONES 3 AND 4 (feet) X 304.8 for mm
1. Bearing wall system	1. Light-framed walls with shear panels		
	a. Wood structural panel walls for structures three stories or less	~~2.0~~N/A	~~65~~ N/A
	b. All other light-framed walls	~~2.0~~N/A	~~65~~ N/A
	2. Shear walls		
	a. Concrete	2.0	160
	b. Masonry	2.0	160
	3. Light steel-framed bearing walls with tension-only bracing	1.6	65
	4. Braced frames where bracing carries gravity load		
	a. Steel.	1.6	160
	b. Concrete[3].	1.6	-
	c. Heavy timber	1.6	65
2. Building frame system	1. Steel eccentrically braced frame (EBF)	2.0	240
	2. Light-framed walls with shear panels		
	a. Wood structural panel walls for structures three stories or less	~~2.0~~N/A	~~65~~ N/A
	b. All other light-framed walls	~~2.0~~N/A	~~65~~ N/A
	3. Shear walls		
	a. Concrete	2.0	240
	b. Masonry	2.0	160
	4. Ordinary braced frames		
	a. Steel.	1.6	160
	b. Concrete[3].	1.6	-
	c. Heavy timber	1.6	65
	5. Special concentrically braced frames		
	a. Steel	2.0	240
3. Moment-resisting frame system	1. Special moment-resisting frame (SMRF)		
	a. Steel	2.0	N.L.
	b. Concrete[4]	2.0	N.L.
	2. Masonry moment-resisting wall frame (MMRWF)	2.0	160
	3. Concrete intermediate moment-resisting frame (IMRF)[4]	2.0	-
	4. Ordinary moment-resisting frame (OMRF)		
	a. Steel[5]	2.0	160
	b. Concrete[6].	2.0	-
	5. Special truss moment frames of steel (STMF)	2.0	240
4. Dual systems	1. Shear walls		
	a. Concrete with SMRF	2.0	N.L.
	b. Concrete with steel OMRF.	2.0	160
	c. Concrete with steel IMRF[4].	2.0	160
	d. Masonry with SMRF	2.0	160
	e. Masonry with steel OMRF	2.0	160
	f. Masonry with steel IMRF[3].	2.0	-
	g. Masonry with masonry MMRWF	2.0	160
	2. Steel EBF		
	a. With steel SMRF	2.0	N.L.
	b. With steel OMRF.	2.0	160
	3. Ordinary braced frames		
	a. Steel with steel SMRF	2.0	N.L.
	b. Steel with steel OMRF	2.0	160
	c. Concrete with concrete SMRF[3].	2.0	-
	d. Concrete with concrete IMRF[3]..	2.0	-
	4. Special concentrically braced frames		
	a. Steel with steel SMRF	2.0	N.L.
	b. Steel with steel OMRF	2.0	160
5. Cantilevered column building systems	1. Cantilevered column elements	1.4	35[7]
6. Shear wall-frame interaction systems	1. Concrete[6].	2.0	-
7. Undefined systems	See Sections 1629A.6.7 and 1629A.9.2	-	-

N.L.-no limit

[1]See Section 1630A.4 for combination of structural systems.

[2]Basic structural systems are defined in Section 1629A.6.

[3]Prohibited in Seismic Zones 3 and 4.

[4]Prohibited in Seismic Zones 3 and 4, except as permitted in Section 1633A.2.

[5]Ordinary moment-resisting frames in Seismic Zone 1 meeting the requirements of Section 2213A.6 may use an R_I. Value of 2.0.

[6]Prohibited in Seismic Zones 2A, 2B, 3 and 4. See Section 1633A.2.7.

[7]Total height of the building including cantilevered columns.

TABLE A-16-F – SEISMIC COEFFICIENT, C_{AM}

TABLE A-16-G – SEISMIC COEFFICIENT, C_{VM}

Adopt Entire 1997 UBC Chapter 17 As Amended: [OSHPD 1, 4]

Legend for Express Terms – 1) California amendments are shown in italics, 2) New California amendments are shown in italics and <u>underlined</u>, and 3) language to be repealed is shown in ~~strikeout.~~

The express terms below indicate existing California amendment sections (italicized) being carried forward into the 2001 CBC and their placement among UBC model code text. In some cases, it was necessary to renumber the existing California section for proper placement within the model code text. Where there is a new, modified or repealed California amendment, the entire text of that section is indicated showing the change(s).